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FEBRUARY, 1837.

## Practical and Theoretical Mechanics.

*Report of the Committee of the Franklin Institute of the State of Pennsylvania on the Explosions of Steam Boilers, of Experiments made at the request of the Treasury Department of the United States.* PART II. *Containing the report of the sub-committee to whom was referred the examination of the strength of the materials employed in the construction of Steam Boilers.*

*To the Committee of the Franklin Institute of the State of Pennsylvania, on the Explosions of Steam Boilers:*

GENTLEMEN—The sub-committee, to whom was referred the examination of the STRENGTH OF MATERIALS employed in the construction of Steam Boilers, beg leave to submit the following REPORT:

WHILE it is important to know the causes which may produce a dangerous developement of elastic forces in the interior of steam boilers, it is obviously not less so, to understand aright the efficacy of those means on which we rely for confining or controlling their energies. Hence, in investigating the causes of explosions, it is both natural and expedient, to examine separately those facts and principles which concern the *divellent* and the *quiescent* forces respectively. The number and variety of circumstances, which affect the character and durability of materials of which steam boilers are formed, are probably not less than of those which tend to modify the action of the fluids which they contain. In this view of the importance to be attached to the subject of the strength of materials, it may be considered remarkable, that while numerous investigations have been made as to the causes of danger, so little should have been attempted in regard to the most direct and obvious means of security. Before the series of experiments here detailed had been commenced, the necessity for such an investigation had been repeatedly pointed out, in public and private lectures, on the steam engine; the reasons assigned for instituting the inquiry, being the very general and unsatisfactory nature of those results,

which are given in practical treatises, respecting the strength of metals, as dependant on the mode of manufacture, and on the different temperatures and other circumstances to which they are exposed. We had, it is true, a considerable number of results, obtained at different periods, by experiments on the direct cohesion of wrought iron.*

They were, however, in general, undertaken for purposes very different from those which prompted the present investigation.

Few of the experimenters had in view the influence of temperatures on tenacity; and even those data which they furnish for calculating the proper thickness of metal to be employed at ordinary temperatures, in constructing steam boilers are liable to much uncertainty, owing to the diversity in the results themselves. Laborious and protracted as has been this investigation, still the practical importance of the subject has appeared to warrant a careful survey, and a diligent comparison of the various facts which might influence the practice of those who desire to attain a secure action in the steam boiler.

Without entering therefore into all the delicate questions, which, had a mere scientific view been indulged, we might have been prompted to examine, it has been the aim of the committee to obtain and present such classes of facts as both scientific and practical men may make subservient to their respective purposes.

The questions, which in the course of this inquiry, it has been found necessary to investigate, may be classed under three general divisions.

1. PRINCIPAL,
2. INCIDENTAL,
3. SUBSIDIARY.

I. *Principal.* 1. What is the absolute tenacity per square-inch bar of rolled boiler iron, at ordinary temperatures, and to what irregularities is it liable?

2. The same for rolled copper?

3. What is the effect of increased temperature on the tenacity of iron and copper?

4. What is the tenacity of wrought iron, manufactured by other means than rolling into plates;—as by rolling it into bars or rods, by hammering and wire-drawing?

5. What are the relative advantages of iron made by refining from different sorts of pig metal and their mixtures?

6. What is the comparative value of sheet iron manufactured by the processes of puddling, blooming and piling respectively, and in the last case, what influence have repetitions of the process?

* The following brief table contains some of the general results, obtained by different authors, as the strength of wrought iron.

| *Name of the Experimenter.* | *Strength in lbs. per sq. inch.* | *Name of the Experimenter.* | *Strength in lbs. per sq. inch.* |
|---|---|---|---|
| Muschenbrock, | 73.100 | Telford—Swedish iron, | 64.960 |
| Perronet—on square bars, | 61.083 | Brown—Welsh iron, | 57.075 |
| Perronet—on round bars, | 60.086 | Brown—Swedish, | 49.796 |
| Buffon, | 84.730 | Brown—Russian iron, | 59.472 |
| Poleni, | 63.390 | Martin—(Fr.) St. Chambaud iron, | 49.000 |
| Rennie—on "English iron," | 55.843 | Martin—Fourchambauldt iron, | 47.964 |
| Brunel—"Best English," | 68.544 | Martin—Superior English, | 52.823 |
| Brunel—"Best-best English," | 72.352 | Martin—English best cable, | 49.251 |
| Telford—Welsh iron, | 65.520 | | |
| Telford—Staffordshire iron, | 60.928 | Rennie—Copper, | 33.792 |

7. What is the effect of piling into the same slab, iron of different degrees of fineness?

8. What is the comparative tenacity of rolled iron, in the longitudinal, diagonal and transverse directions of the rolling respectively?

9. What influence may be produced, by long and repeated use, towards modifying the character of boiler iron?

II. *Incidental.* 1. What is the specific gravity of the specimens submitted to examination?

2. What elasticity is found in the metals under different circumstances of the trial?

3. What relation exists between the force which will produce a permanent elongation in a bar, and that which will entirely overcome its tenacity?

4. What amount of elongation may the several kinds of metal undergo before fracture?

5. Does the amount of *constriction* or diminution of area, at the section of fracture, bear any relation to the absolute strength of the metals, to the direction in which the strips are cut from the plate, to the breadth and thickness of the strips themselves, or to the temperature under which the trial is made?

6. What is the effect of the rivets on the total strength of a boiler?

III. *Subsidiary.* 1. What is the friction of the apparatus employed to determine tenacities?

2. What is the amount of its elasticity?

3. What is the latent heat of the vapour of water?

4. What is the specific heat of iron, copper and glass, respectively?

5. What is the rate of heating of a given mass of liquid, when subjected to the direct action of a solid of higher temperature?

6. At what rate will the same mass of liquid change its temperature by the action of air alone?

From the foregoing statement, it will be seen that more than twenty distinct topics have demanded the attention of the committee. They have felt strongly inclined to embrace some other points of great practical and scientific importance, but the time already unavoidably consumed, and the very limited means which the other branches of inquiry and experiment on explosion left to be appropriated to the purposes of this sub-committee, compelled the relinquishment, for the present, of those objects which do not immediately concern the construction and use of steam boilers.

The discussion of the questions above enumerated, will necessarily follow an order somewhat different from that in which they are here stated. A view of the apparatus, employed by the committee, claims the first notice. The origin and preparation of the materials to be tested, will also precede the detail of experiments.

### *Machine for proving the strength of materials.*

The apparatus used, by the committee, for the direct determination of the principal questions regarding the strength of the specimens submitted to examination, is represented in plate I. M is a strong frame of oak timber, the two longer sides five feet in length, fourteen inches deep, and six inches thick.

The two shorter, or end pieces, which project beyond the *sides* to the distance of three inches, are each two feet eight inches long, seven and a half inches thick, and fourteen inches deep.

Between the two side pieces, (one of which is in the figure removed, to exhibit the interior or working parts,) is a space fourteen and a half inches

wide, affording room for a screw, cross-head, guide-rods, connecting blocks and wedges, to hold the specimens under trial; and also for the heating apparatus in experiments at high temperatures.

These four massive blocks or beams of timber, are held together by strong screw bolts, passing through mortises in the end pieces, along tenons into screw nuts imbedded in the timber of the longitudinal beams.

The frame is supported, as represented in the figure, by four firm trussel legs, six inches square, tied together near the bottom, and fastened as well to the ties as to the frame above, by mortising and bolting. The top of the frame is three feet eight inches above the floor on which the machine rests.

Through one end A, of the frame M, about six inches below the top, and centrally between the two side beams of the frame, passes the screw S, $2\frac{3}{4}$ inches in diameter, and three feet long, cut into threads $\frac{6}{10}$ of an inch apart. Near the head of the screw, is a neck turned rather deeper than the threads, to allow a clamp collar to embrace it; which, together with a strong cast iron plate, against which the head of the screw works, prevents any longitudinal motion of the screw itself.

N is the box or nut of this screw which by the revolution of S, either approaches to or recedes from the end A of the frame; $s$, $s$, are two guide-rods, one on each side of the screw, level with its axis and near the inner faces of the longitudinal beams of the frame, serving to support a cross head that contains in its central ring the nut N, and embraces by loops at its extremities the two guide-rods. The purpose of these loops is to prevent the nut from turning by the revolution of the screw.

The cross head thus secured is united by two strong straps or bars of iron $i$, $i$, 2 inches wide by half an inch thick, to a block of iron $b$, which is also furnished with two projecting arms that rest on the guide-rods already described. This block as well as the two others $b'$ and $b''$ is 4 inches long, 4 inches deep, and $1\frac{1}{4}$ inches thick, being perforated centrally in the direction of its thickness with a hole in the form of the frustum of a square pyramid, the purpose of which is to admit of wedges placed within them to hold the bars of metal under trial. A more detailed description of these will be given hereafter.

The block $b'$ is connected to $b$ by a separate pair of straps $i'$, $i'$, and has arms reposing on the guide-rods, or when necessary, admitting a vertical semi-revolution, so as to be laid over backward between the straps $i$, $i$. This latter disposition of the block $b'$ was made whenever specimens of 20 or 30 inches in length were to be tried; but when those of only a few inches in length were under trial, $b'$ was used in the position represented in the figure.

The block $b''$ is connected by the strong iron straps $i''$, $i''$, which pass freely through a suitable opening in the head B of the frame, to the lever L. One of these straps is seen at $e$, the other being on the posterior side of the lever, with which they are united by means of a steel bolt turned with care and well polished. The straps are kept in place by a head, screw nut and washers, on the bolt. This lever is of the *rectangular* kind, the longer arm being horizontal, the shorter vertical, and the angular point being in the axis of a second or lower bolt which serves as a fulcrum.

At the end next the frame, the lever has a breadth or depth of seven inches and a thickness of one inch. Towards the opposite extremity or that on which the weights are placed, it diminishes to a breadth of four inches, and a thickness of $\frac{3}{8}$ of an inch. The upper edge of the beam is straight to within 24 inches of the broader end, where it curves upwards, affording a massive support for the upper bolt already described. In a ver-

tical direction beneath that bolt, and in the prolongation of the upper straight edge of the lever, is the position, as already indicated, of the second steel bolt, serving for a gudgeon, on which the lever turns. The distance between the axes of the two bolts is 2.914 inches, which is therefore the length of the shorter arm of the lever. The bolts are very nearly of the same diameter, being each about 1.086 inches. The lower bolt rests against a plate of cast iron, having suitable projecting cheeks, with bearings adapted for its reception.

A strap from the top of each cheek comes down over the bolt, and is fastened with a thumb screw, to prevent the lever being thrown out of place by the recoil of the machine. The two guide-rods *s*, *s*, pass through this cast iron plate, as well as through that which serves as a collar to the screw head, S, on the opposite end of the frame. The lever is formed of the best wrought iron, and weighs $164\frac{3}{16}$ pounds, the matter being so distributed that if not neutralized by counter weights, its effect in straining any bar attached horizontally to the upper bolt would have been equal to 2495¼ lbs. To obviate this, and to prevent the weight of the lever from adding anything to the friction, it is accurately counterpoised by means of weights C and C,′ corresponding to the parts of its mass which they are respectively required to sustain. Thus the weight of C, the larger counterpoise, is 103 pounds 12 ounces, that of C′ 60 pounds 7 ounces. The former is, however, increased to counterpoise likewise, one-half the weight of the two straps *i*″, *i*″, the other half resting, as will be seen, on the horizontal guide-rods *s*, ′*s*.

The axes of the pullies *p*, *p*′, over which the cords *r*, *r*′ pass, are furnished with cavities to receive steel pivot-points, in order to reduce, as far as practicable, the friction of these parts. The diameter of these pullies is 12 inches.

The iron stirrup, to which the cord *r* is attached, is applied to the lower bolt or fulcrum of the lever, the projecting ends of which roll on straight, horizontal edges, forming the bottom of two loops with which the stirrup is furnished.

By means of the suspending apparatus above described, the lever is enabled to obey any force acting vertically on its longer arm, with the advantage of ample strength and stiffness, combined with the condition of a theoretical lever, in respect to the *gravity of parts*.

There are two modes of operating by which a bar of metal, placed in the machine between *b*′ and *b*″ might be broken, so as to ascertain the tenacity.

The first is to apply the force of the screw S to strain the bar in raising a weight W suspended at any convenient point on the arm *h* of the lever; the second is to employ the screw only to regulate the height of that arm, and to restore it when relieved of the weights, to the horizontal position, whenever the extension of the bar had allowed it to fall below that position.

The latter method was with very few exceptions, adopted by the committee,—both because it allowed of a more exact determination of the breaking weights, by a small addition at a time, and because it rendered the effect of the friction constant in its kind, being always in opposition to the gravitating force of the weight W, and *subtractive*, in the calculation.—In order to apply this mode of action without requiring correction for the stiffness of the cord *r*′ and the friction of the pulley *p*′, it was only necessary after adjusting the weight C′, to remove so much as would allow the arm *h* of the lever to descend upon the slightest jarring of the machine. The tenacity of the bar

and the friction at the fulcrum, were then the only resistances to the motion of the weight W.

The purpose of the tackle of pullies P, is to elevate the scale pan and weight after they have descended to the floor, in order, by turning the screw S, to counteract the elongation of the bar under trial, and again to commence operations with the descending motion of the arm *h*. The power of the operator is applied to the tackle by means of the windlass *w*, furnished with its crank, ratchet wheel and click. The upper edge of the lever was graduated into parts distant from each other just ten times the length of the shorter arm.

By the aid of these several appendages, the machine allows the most gradual additions to be made to the divellent force applied to the specimens, breaking each with a descending movement, and consequently, rendering the *friction* definite in the direction of its influence, being, as before stated, always subtractive.

The very few cases in which the mode of operation rendered it *additive*, are particularly mentioned in the tables.

At the outer extremity of the lever, and in the prolongation of its upper edge, is placed a style *z*, serving as an index to the graduated arc *a*, which is divided into minutes of a degree. The point of the style is 10 feet 3 inches from the axis of motion in the lever, and the length of the entire circumference which it would describe 772.8276 inches. Hence each degree is 2.14674 inches, and each minute, as measured on the arc, is .035779 of an inch. The whole extent of the arc *a* is about 5 degrees, the zero, or point of horizontal position being placed 3 degrees from the upper extremity. The chief use of this arc was to determine approximately the *elasticity of the bars*, and of the machine itself, as preliminary to that inquiry. The weights W, in the scale-pan, (which, with its suspending chains, cross-bars, &c. weighs 56 pounds,) were, in every case, applied on the lever, at the third mark, a distance from the axis of motion 30 times as great as that between the axes of the two bolts, or $30 \times 2.914 = 87.42$ inches.

### *Friction of the Machine.*

The amount of friction of the machine already described for testing the tenacity of metals, was an object requiring particular investigation before any thing more than a comparative value could be assigned to the results which were afforded by the experiments.

To determine this point, it was deemed advisable to ascertain under various loads what proportion the weight which was sustained by the machine, after it had been raised by the screw S till the index stood at zero on the arc *a*, bore to that which, after the lever was relieved and then loaded again with the same weight, would cause it once more to descend to zero.

Between the heads $b'$ and $b''$ was placed a strong bar of iron, 1 inch wide by $\frac{3}{4}$ of an inch thick. Two methods were then pursued for the purposes of mutual verification.

1. A certain weight was placed in the pan suspended at *h*, and the screw S turned until, as before mentioned, it was raised to a level so that *z* stood at zero on the graduated arc. The windlass *w* was then employed to raise the scale-pan and entirely relieve the lever. On again restoring the weights, the index remained some minutes of a degree above 0, and an additional quantity of weight was necessary, to bring it once more down to that level. As, in this case the weight added served to increase the friction, it is manifest that the comparison of it with the whole weight, itself in-

cluded, must be necessary in order to show the relation between the weight at first raised and that part of it, which represented the friction of the machine. When the weight was raised by the screw, the bar which connected the heads $b'$ $b''$, must have sustained a strain composed of the weight raised *added to* the friction of the machine; whereas when the weight was let on by the windlass while the index was at some distance above 0, the bar sustained a strain represented by the weight borne, *diminished by* the friction.

II. The lever was caused to rest on a solid support near the extremity, the index being opposite to zero on the arc, and in that position the scale-pan was loaded with the weight under which it was intended to try the friction. The screw S was then carefully turned to strain the bar and bring the loaded arm of the lever barely off of the support. The weights were next raised by the windlass and the recoil of the machine raised the lever to a certain elevation, from which it was once more depressed by replacing the weights upon it, and adding such an amount as would just depress the arm to the level of its original support.

The first of the above methods gives the *double*, and the second the *single*, friction of the machine. The following table exhibits the weights in the scale-pan, the weight representing the friction when the first method was employed; the same for the second method; and the ratio of the friction to the total weight sustained by the lever. A correction is required particularly at the higher pressures, on account of the increased elasticity in the machine under the added weights, which actually brought the index down to zero sooner than it would have arrived at it, by the simple effect of a strain upon the lever regarded as inflexible.

The machine was kept constantly well oiled, still a trifling difference may possibly have existed in regard to its condition at different times; but no influence of this sort, was ever found sufficient to determine the rupture of a bar, after the weight had been taken up, the gudgeons newly oiled, and the same weight replaced, which it had borne previous to that operation.

TABLE I.

| No. of the experiment. | Weight applied to the lever. | Double Friction. | | | Single Friction. | | |
|---|---|---|---|---|---|---|---|
| | | Weight required to counterpoise the double friction. | Ratio of friction to weight by the method of double friction. | No. of repetitions furnishing the mean result on double friction. | Weight required to counterpoise single friction. | Ratio of friction to weight by the method of single friction. | No. of repetitions furnishing the mean result on single friction. |
| 1 | 56 | 6.00 | .050+ | 3 | 3.00 | .050+ | 1 |
| 2 | 112 | 10.82 | .051+ | 7 | 5.79 | .051+ | 6 |
| 3 | 168 | 17.62 | .052+ | 4 | 9.06 | .051+ | 4 |
| 4 | 224 | 24.85 | .055+ | 10 | 12.75 | .053— | 5 |
| 5 | 280 | 28.16 | .050+ | 6 | 14.71 | .050— | 7 |
| 6 | 336 | 35.30 | .053+ | 5 | 17.25 | .049— | 6 |
| 7 | 392 | 38.33 | .047+ | 4 | 20.42 | .050— | 4 |
| 8 | 448 | 42.50 | .048+ | 4 | 22.64 | .048+ | 7 |
| 9 | 504 | 45.50 | .045+ | 1 | 26.80 | .050+ | 7 |
| | | Mean .050 | | Tot. 44 | Mean .050 5 | | Tot. 47 |

From the above table it appears that the second method gave results more nearly in accordance with each other than the first, but it will also be noticed that forty-four observations with the first gives a mean value sensi-

bly identical with that obtained from forty-seven experiments with the second method of trial above described. We were hence led to adopt 5 per cent. of the weight as the effect of the friction of the machine. The bolts are of well polished steel and the lower bearing of cast iron, and the upper one or the eyes of the straps *i''*, *i'''*, of wrought iron.

This relation of friction to pressure between these substances as deduced from the experiments of the committee, will be found to correspond very nearly with that obtained by Mr. Wood when operating on railway carriages.*

### *Elasticity of the Machine.*

In order to determine, in particular cases, the amount of elasticity exhibited by the bars under trial, it became necessary to ascertain the elasticity of the machine, when loaded with different weights. Several series of trials were accordingly made expressly with a view to this object.

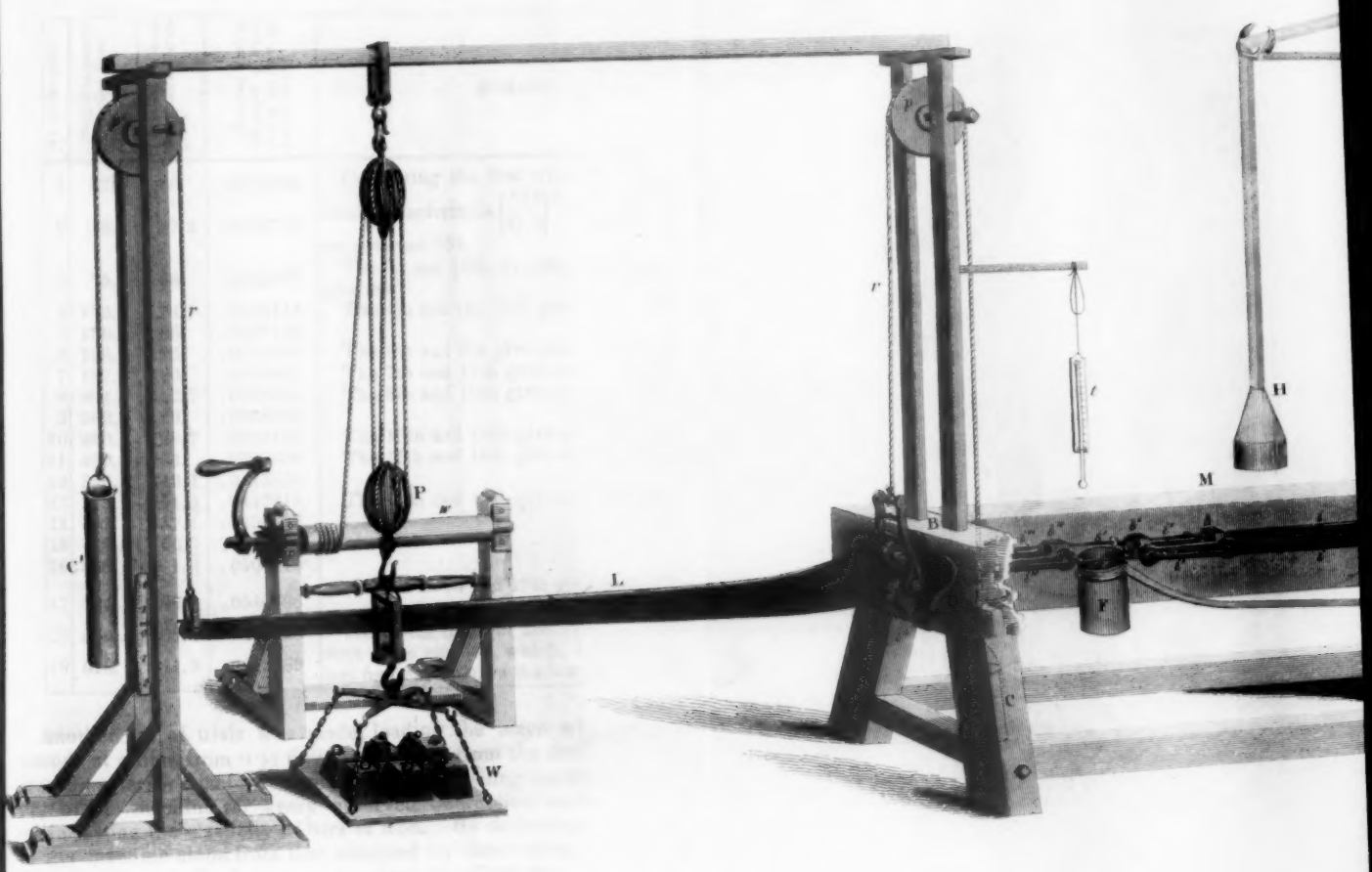
Putting into the machine, in place of a bar to be broken, one which was intended not to yield sensibly to the strains applied, and not in any case to be permanently elongated by them, different weights were appended to the lever, and allowed to remain until the latter had become stationary. They were then carefully raised by the windlass, and the lever allowed to rise by the recoil until it became entirely free from strain. The number of degrees and minutes on the arc *a*, traversed by the index, was then noted; the weight replaced, and the trial repeated until it was ascertained that no error of observation had occurred.

Three series of operations were performed each beginning with the lever 3°. 30′ above zero, when entirely unloaded, but fully in contact with its bearings. Weights were then added by 56 pounds at a time, and the depression below 3°.30′, produced by each addition, was noted. This was continued until weights had been added sufficient to bring the index to 0, which was effected with 11 weights of 56 pounds each.

If the *lever* had been entirely inflexible, the natural sine of the angle of elevation after being relieved might have been considered the measure of the compression of parts sustained by the frame, links, &c. under each weight; for as the shorter arm of the lever is only 2.914 inches in length, while the bar and connecting straps are more than 5 feet, the direction of the horizontal bar may be considered sensibly constant.

The following table contains the results of the experiments just described, together with those of another set in which the operations were in every respect similar, except that the weights were applied by 37½ pounds at each time instead of 56 pounds. The natural sines are added, by comparing which with the respective *compressing forces*, it will be found that the law which governs the *elasticity* of the machine is, that *the latter is proportionate to the fifth root of the cube of the compressing force.*

* See Wood on Railways, Smith's edition, Philadelphia 1832, p. 202. The mean of nine out of twelve experiments there detailed is exactly 5 per cent. for the friction between steel and cast iron.

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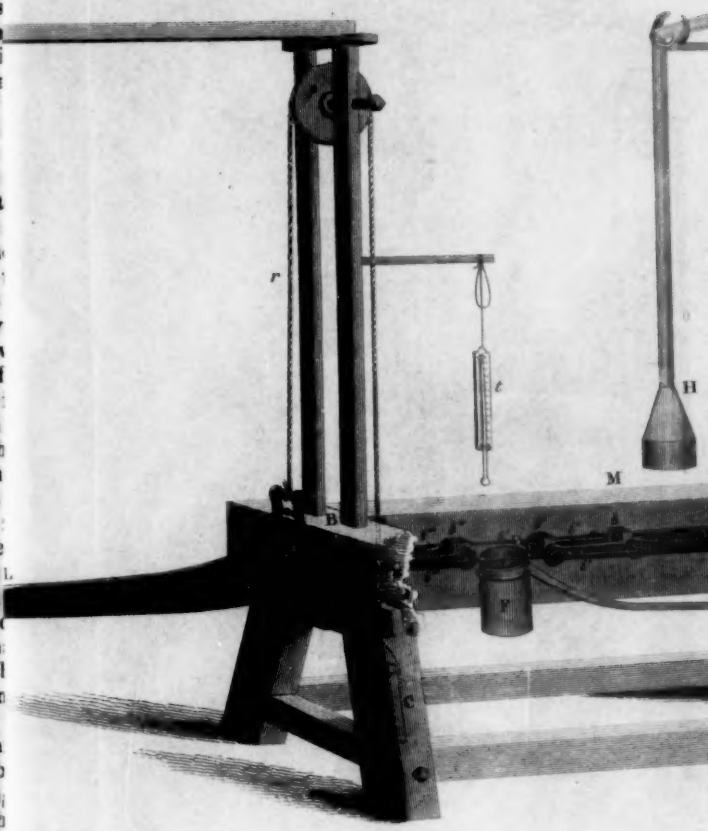


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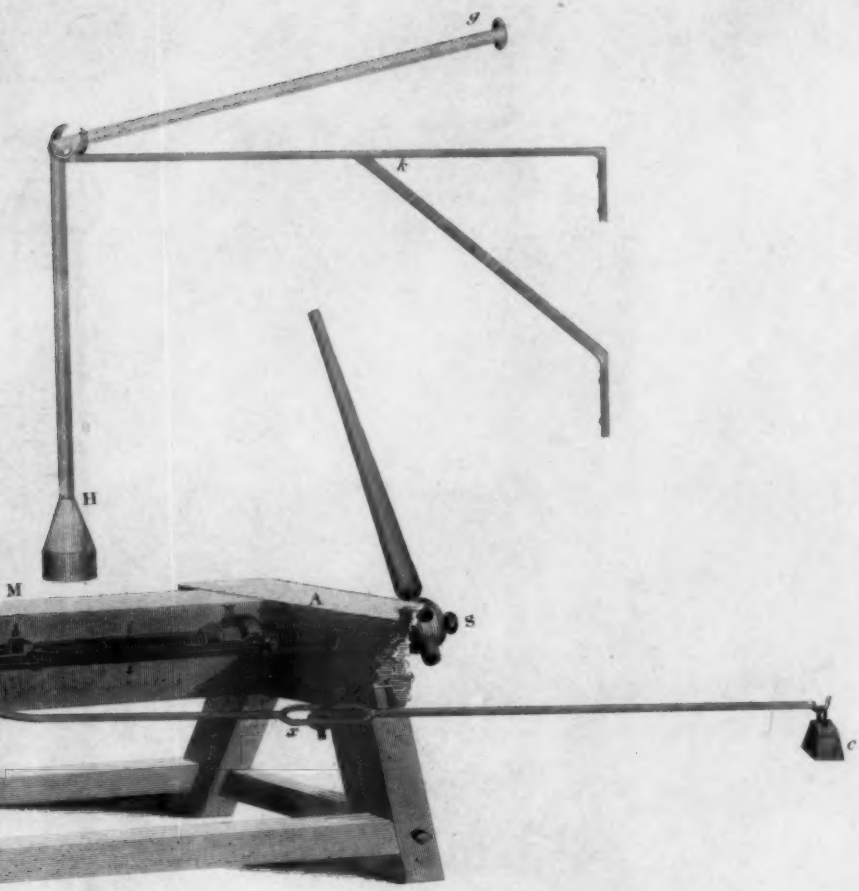


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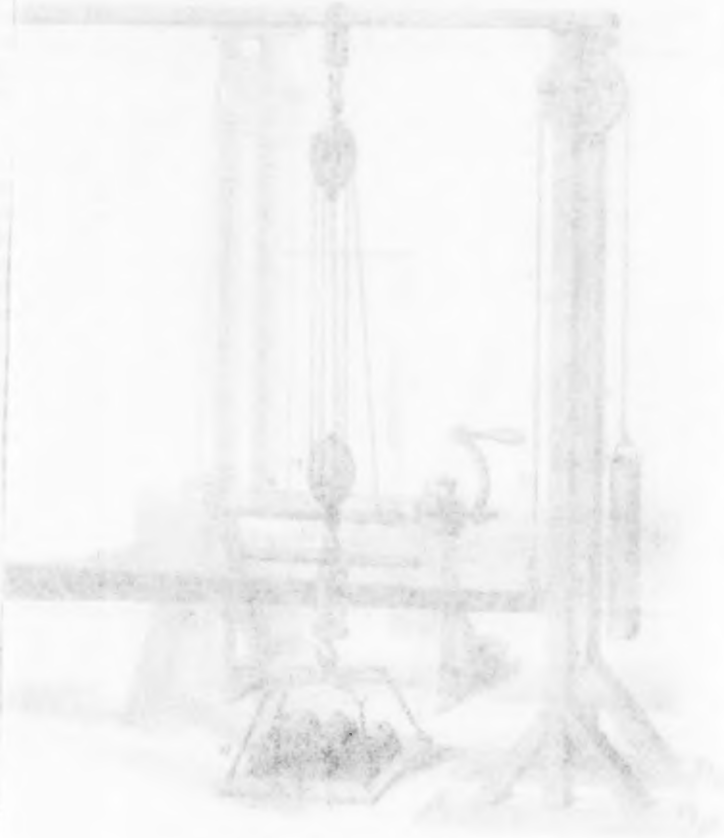


## TABLE II.

| *No. of the trial.* | *Weight in pounds producing compression.* | *Recoil of the lever in minutes of a degree.* | *Natural sine of the angle of elevation of the lever after the recoil.* | *REMARKS.* |
|---|---|---|---|---|
| 1 | 37.5 | 40.′ | .0116353 | Comparing the first with the last experiment by the formula $\left(\frac{616}{37.5}\right)^x = \frac{\text{nat. sin. } 211.5'}{\text{nat. sin. } 40'}$ we get $x$=0.594. |
| 2 | 56. | 47.2 | .0136713 | |
| 3 | 75. | 58. | .0168707 | The 3d and 16th, by a similar comparison, give $x$= 0.608. |
| 4 | 112. | 74.7 | .0218149 | The 4th and the 19th give $x$= 0.606. |
| 5 | 150. | 86. | .0250138 | |
| 6 | 168. | 95. | .0276309 | The 6th and 8th give $x$= 0.600. |
| 7 | 187.5 | 100. | .0290847 | The 7th and 17th give $x$= 0.627. |
| 8 | 224. | 112.7 | .0328644 | The 8th and 10th give $x$= 0.595. |
| 9 | 262.5 | 120. | .0348995 | |
| 10 | 280. | 128.7 | .0375158 | The 10th and 12th give $x$= 0.560. |
| 11 | 300. | 134. | .0389692 | The 11th and 18th give $x$= 0.641. |
| 12 | 336. | 143.4 | .0415850 | |
| 13 | 375. | 154.5 | .0447818 | The 13th and 15th give $x$= 0.583. |
| 14 | 392. | 157.4 | .0456536 | |
| 15 | 412.5 | 166.3 | .0482687 | |
| 16 | 448. | 171.9 | .0500119 | |
| 17 | 504. | 186. | .0540788 | The 2d and 17th give $x$=0.625<br>Mean 0.603 |
| 18 | 560. | 199.7 | .0581448 | Hence the mean of the above 10 comparisons gives $x$=.603, which, by rejecting the last figure, furnishes the law above stated. |
| 19 | 616. | 211.5 | .0613389 | |

Another set of trials was made, loading the lever with weights by 7 pounds at a time from 0 to 609 pounds; and from the results of this and the preceding series a table was constructed, furnishing the column of elasticities of the machine for every observed depression under given weights when testing the elasticity of bars of iron. By deducting the elasticity due to the machine alone from that obtained by observation, we get the measure, in minutes of a degree, of the elasticity of the bar.

In the table of elasticities actually observed will be found various numbers between 5′ and 73′. To facilitate the comparison of each observed elasticity with the length of the bar on which the trial was made, the following table is annexed in which the natural sine belonging to each number of minutes has been multiplied by 2.914, the length in inches of the shorter arm of the lever.

**TABLE III.**

| Observed elasticity in parts of the arc. | Corresponding extension and recoil of the bar in inches. | Observed elasticity. | Extension and recoil in inches. | Observed elasticity. | Extension and recoil in inches. | Observed elasticity. | Extension and recoil in inches. | Observed elasticity. | Extension and recoil in inches. |
|---|---|---|---|---|---|---|---|---|---|
| 5′ | .0042323 | 19′ | .0160829 | 33′ | .027965 | 47′ | .039835 | 61′ | .051695 |
| 6 | .0050788 | 20 | .0169295 | 34 | .028821 | 48 | .040680 | 62 | .052539 |
| 7 | .0059253 | 21 | .0177760 | 35 | .029665 | 49 | .041529 | 63 | .053385 |
| 8 | .0067718 | 22 | .0186525 | 36 | .030508 | 50 | .042370 | 64 | .054230 |
| 9 | .0076183 | 23 | .0194690 | 37 | .031360 | 51 | .043223 | 65 | .055076 |
| 10 | .0084648 | 24 | .0203455 | 38 | .032200 | 52 | .044060 | 66 | .055920 |
| 11 | .0093114 | 25 | .0211618 | 39 | .033050 | 53 | .044903 | 67 | .056792 |
| 12 | .0101579 | 26 | .0220083 | 40 | .033839 | 54 | .045750 | 68 | .057639 |
| 13 | .0110041 | 27 | .0228548 | 41 | .034769 | 55 | .046596 | 69 | .058484 |
| 14 | .0118506 | 28 | .0237013 | 42 | .035580 | 56 | .047439 | 70 | .059330 |
| 15 | .0126972 | 29 | .0245478 | 43 | .036425 | 57 | .048288 | 71 | .060173 |
| 16 | .0135437 | 30 | .0253941 | 44 | .037270 | 58 | .049158 | 72 | .061019 |
| 17 | .0143902 | 31 | .0262406 | 45 | .038115 | 59 | .050009 | 73 | .061865 |
| 18 | .0152367 | 32 | .0270871 | 46 | .038989 | 60 | .050848 | 74 | .062710 |

Instead of the numbers in the table, a tolerably near approximation to the true temporary elongation corresponding to each observed elasticity of the bar in minutes might have been obtained, by multiplying the number of minutes by .000847 inch, the length of one minute on the arc of a circle, the radius of which is 2.914 inches. This would give a result sensibly correct, especially for all numbers of minutes under 60.

*Sources from which the materials were obtained.*

The materials on which the committee have performed the experiments detailed in this report, were procured from various sources, a considerable quantity having been collected previous to their appointment by one of its members, then making arrangements for a private course of investigations on several scientific and practical points, relating to tenacity. Other specimens were voluntarily offered, or kindly supplied at the request of the committee by the different manufacturers, or other persons to whom application was made for that purpose. In several instances, more specimens of the same iron were furnished than will be found mentioned in the tables as derived from the same quarter;—the whole number obtained being about two hundred and fifty, and the number tried about one hundred and fifty. As the aim of the experiments was the establishment of such practical truths as might be found generally useful in regard to the manufacture and employment of materials for steam boilers, it was not deemed necessary to enter into a minute comparison of the merit of different manufacturers from whom the materials were received, nor to limit the inquiry to any given number of specimens or of trials on those derived from each source. The reader, will, however, be able to institute such comparisons as his curiosity may dictate,—the tables furnishing all the facts, (as well as the names of the manufacturers when known,) which have been obtained by the committee, in regard to the origin and manufacture of the different specimens.

Among the names of those from whose manufactories specimens have been received, are Messrs. MASON & MILTENBERGER, H. S. SPANG & SON, BARNET SHORB, H. BLAKE & Co. and SHOENBERGER & SON, of Pittsburg; S. E. H. & P. ELLICOTT, and E. T. ELLICOTT & Co. of Baltimore; the SALISBURY IRON COMPANY, of Salisbury, Connecticut; Messrs. YEATMAN & WOODS, of Nashville, Tennessee; Mr. MASSEY, of Maramec, Missouri; R. LUKENS, of Coatesville, Chester county, Pennsylvania; GEORGE PENNOCK, McWilliamstown, in the same county; Messrs. GRUBBS, Lancaster county, Pa., HARDMAN PHILLIPS, Esq., Clearfield county, and Messrs. VALENTINE & THOMAS, Centre county, Pa. To Messrs. A. & G. RALSTON the committee were indebted for specimens of boiler, bolt, and railroad iron, of English manufacture, which served as means of comparison between the foreign and the domestic material, and from other importers they procured those of Russian and Swedish manufacture, for the same purpose. All the samples of American iron thus far mentioned, were manufactured by the aid of charcoal. A single specimen furnished by Mr. P. RITNER, of Carthouse's Place, on the West Branch of the Susquehanna river, was made by smelting with coke.

The specimens of boiler copper, tried by the committee, were obtained from the establishment of JOHN M'KIM, jr. & SON, of Baltimore.—To the above, and several other gentlemen who were active in procuring the materials, and otherwise forwarding the objects of this inquiry, the committee are bound to offer their grateful acknowledgments.

### *Preparation and gauging of the specimens.*

The experiments were made on materials in several different forms, and as the results are in some measure dependent on the circumstances now referred to, it seems proper to describe those several conditions, together with the method of obtaining the areas of transverse sections at the points of fracture.

As the greater number of experiments was, of course, made on materials manufactured expressly for steam boilers, the mode of preparing these is of most importance. The strips were in general cut, by shears, from the plates, about 2 or $2\frac{1}{2}$ feet long, and 1 inch wide; and with a view to determine the tenacity in different directions, they were cut either lengthwise, crosswise or diagonally of the direction in which the plate had been rolled.

The tables will be found to indicate, in all cases where rolled iron is under consideration, the direction of the slitting.

On specimens of this kind, trials were made in three ways. *First*, by finding and measuring the area of the smallest section, as the strip came from the shears, and placing it in the machine, applying force till that or some other section gave way. When not broken at the smallest section, the actual area of the point of fracture was ascertained approximately by measuring, after fracture, at a short distance on each side of the broken part, taking care to keep just outside of the constriction or part sensibly diminished by the strain. After thus determining the area previous to trial, a portion of the bar was replaced, and other fractures made, until the specimen had been used up. Fractures on bars, tried in this manner, are referred to in the tables as made at *original sections*. But as the slitting of bars in the manner described necessarily caused some diminution of strength along the edges, and as from accidental causes this diminution was often very unequal, it was apparent that the irregularity in the *strength* might

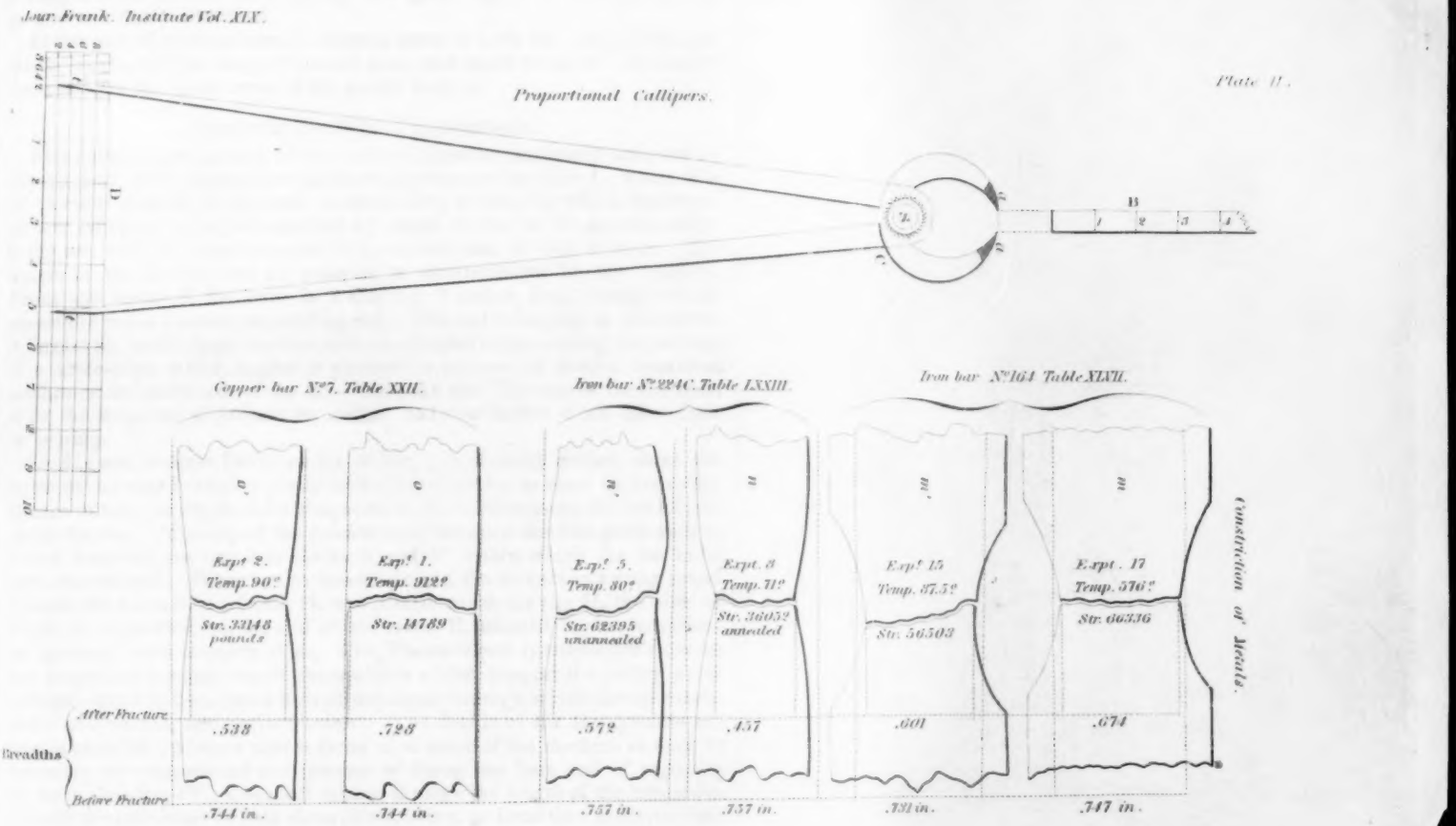
frequently be greater than that in the *breadth* of a strip. To ascertain the mean effect of the shears on bars of this breadth, the second method of trial was adopted.

This consisted in filing away a section of the metal on each side of the strip, in the form of the segment of a circle. At different points, these sections were filed to different depths, with a view of ascertaining how far beneath the surface the metal had been affected. The scale of oxide was also in some cases filed from the surface, but in most instances where the rolls had left the iron tolerably smooth, it was thought best to take the measurements of thickness, as they must be taken in practice with the surface in its natural state. In some instances, it will be found that the fractures did not occur in the filed section, even when a considerable portion of the whole material had been filed away, (see bars 206 and 207, &c., table LII.) In general, however, about $\frac{1}{8}$ of the breadth of the bar being removed by the two opposite sections, the sound part of the metal was attained, and gave results nearly proportionate to the areas of the remaining sections.

But as neither the rolling nor the hammering of iron can give a perfect uniformity of structure, and as consequently the results on very deeply filed sections would not always prove uniform in their indications of strength, it became necessary, in order at once to remove the irregularities proceeding from the slitting, and to compare the advantage of different modes of manufacture, and different kinds of metal employed, as well as to ascertain the maximum and the minimum strength of the same bar at various temperatures, to employ the third method of preparation, that of filing away the edges of the inch bars till they were reduced to $\frac{3}{4}$ of an inch in width throughout their whole length, and also removing completely the scale from both faces, and rendering the thickness as nearly as possible uniform throughout. The bars treated in this manner were next divided through their whole length into spaces of one inch each, marked across with a steel point, numbered at every inch, and subsequently gauged at every mark, both in breadth and thickness. In these measurements, as well as those applied in the two other methods of preparation, the gauging was carried to thousandths of a lineal inch in both directions, giving the areas, true to millionths of a superficial inch. Plate II represents the apparatus used for this purpose, and a portion of a bar prepared for gauging. C is a pair of proportional callipers of brass, pointed at $a$, $a$, with steel. S is a screw head projecting $\frac{1}{2}$ an inch above the face of the instrument, and is $\frac{1}{8}$ of an inch in diameter, being a trifle less in length than the thickness of the two arms of the callipers. The distance $S\,t$ is ten times that of $S\,a$, so that the space beween the points $a$, $a$, is read into tenths, hundredths and thousandths, when that between $t$, $t$, on the diagonal scale D, is found in inches, tenths and hundredths.

Specimens of hammered iron and of iron formed into bars by rolling and slitting were tried with a view to certain comparisons and in these cases all the three modes of preparation applied to specimens of boiler iron were likewise employed. In a few instances specimens were received from the manufacturers in a form which required no alteration before trial, but in the majority of cases they were to be either slit or hammered and filed to adapt them to the purpose of these experiments. In the treatment of boiler-iron, *heating* before trial, was, with few exceptions, avoided. The tables will be found to contain a few experiments on upsetting, annealing and hammer-hardening. They will also exhibit a very limited number of trials on cast iron and steel, but as these materials enter sparingly into the composition of steam boilers, and as their tenacity has been formerly much more exten-

sively examined than that of boiler-plate, it was not considered within the purpose of the present investigation to do more than present a few verifications of the correctness of those results on which practical men commonly relv




is the lever supporting the furnace. The bath is composed of an elliptical copper or sheet iron cup, $4\frac{3}{4}$ inches long, $3\frac{1}{4}$ wide, and 4 inches high with two lips or channels, in the direction of its shorter diameter, each one inch deep, and the same in breadth, to admit the passage of the bar through them, and to contain the packings *w*, *w*, adapted to retain the hot liquid, and cause it to cover the bar *a*. These channels extend each about one inch beyond the sides of the cup, affording room for the straps *y*, *y*, passing beneath them

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The bars of cast iron were tried as they came from the mould, or with very little filing to remove the irregularities of the surface. The specimens of copper were all reduced by filing to a good degree of uniformity, and gauged as already described.

At the foot of each column of original areas in each bar gauged throughout its length, will be found the mean area, and under areas of "sections of fracture" are the mean areas of the points broken.

### *Apparatus for High Temperatures.*

The general arrangement of the parts of apparatus expressly designed for experiments, at the highest temperatures, is presented in plate I., where F is the portable furnace for charcoal, suspended by an iron ring which is fastened on near its upper edge, and attached by means of pins on the opposite sides, to the two ends of a semi-circular fork on one arm of the lever $x$. The weight of the furnace and its contents is counterpoised by the weight $c$. About the centre of the lever is a slit, 6 or 7 inches long, through which passes the end of a screw suspending-rod. The nut belonging to this screw, is furnished, on its upper surface, with an elevated ridge, serving the purpose of a knife-edge, which applies at pleasure to any one of several transverse notches on the under side of the lever along the slit This serves, for the time, to fix the lever and to prevent its sliding endwise unless when lifted from its bearing.

As this nut revolves freely on the screw, a horizontal motion about the screw as an axis is readily given to the lever, while, to raise or lower the furnace in order to regulate the temperature, the knife-edge on the nut affords ample facility. The top of the furnace rises between the two guide-rods $s$, $s$, and between the two iron blocks $b'$ and $b''$ within which the bar to be tried, is confined. When not in immediate use, the furnace is swung round beneath the beam of the frame M, and placed under the cap H, the pipe of which is supported on the end of the crane R, adapted for its reception, and passing into a chimney at $g$. The Thermometer $t$, suspended from an arm projecting beyond one of the uprights which support the pulley $p$, is lowered, when in use, into a bath of hot liquid through which the specimen under trial passes, as described below. The details of the arrangement are seen in plate III., where a plan is given of so much of the machine as may be necessary to comprehend the manner of fixing the bars and of applying the heat. In plate IV., a vertical section through the length of the bar, is exhibited; the references in both these plates, being, so far as they apply to common objects, the same as those in plate I. Thus in plates III. and IV., $i'$, $i'$ and $i''$, $i''$. are the straps of iron connected with the blocks $b'$ and $b''$, which by means of their projecting arms repose on the two guide-rods $s$, $s$. F is the furnace, $t$ the thermometer seen immersed in the bath of hot liquid B, and $x$ is the lever supporting the furnace. The bath is composed of an elliptical copper or sheet iron cup, $4\frac{1}{2}$ inches long, $3\frac{1}{2}$ wide, and 4 inches high with two lips or channels, in the direction of its shorter diameter, each one inch deep, and the same in breadth, to admit the passage of the bar through them, and to contain the packings $w$, $w$, adapted to retain the hot liquid, and cause it to cover the bar $a$. These channels extend each about one inch beyond the sides of the cup, affording room for the straps $y$, $y$, passing beneath them

and rising on each side, near the tops of which are placed two cross-heads, *c*, *c*, and through these pass the tightening screws *n*, *n*, employed in pressing down the packings *w*, *w*. The manner in which the bars are held by the blocks *b'*, *b''*, is seen at *w*, *w'*, where the dove-tailed form of the holes into which the wedges pass and the arrangement of teeth on the steel face of each wedge, are particularly indicated. In adjusting the bars in their place for these experiments, it became necessary to form perfectly secure joints at *w*, *w*, where they pass through the channels before mentioned. In most of the experiments below 600 degrees this was effected by means of loosely spun cotton, wrapped about the bar, for an inch at each point where the screws were to be applied. For temperatures above 600° a packing formed of fibres of iron scraped from wire in the manufacture of weavers' reeds was adopted. This being formed into mats, and rolled in a powder of oxide of tin,—constituted an impervious barrier to the melted metal, particularly after being duly settled and condensed into place, and then firmly compressed by the screws.

Below 600°, the fluid commonly employed was olive oil, and for higher temperatures a mixture of tin and lead. In some cases, however, between the melting point of *tin* and the highest temperatures applied, the latter metal only was used.

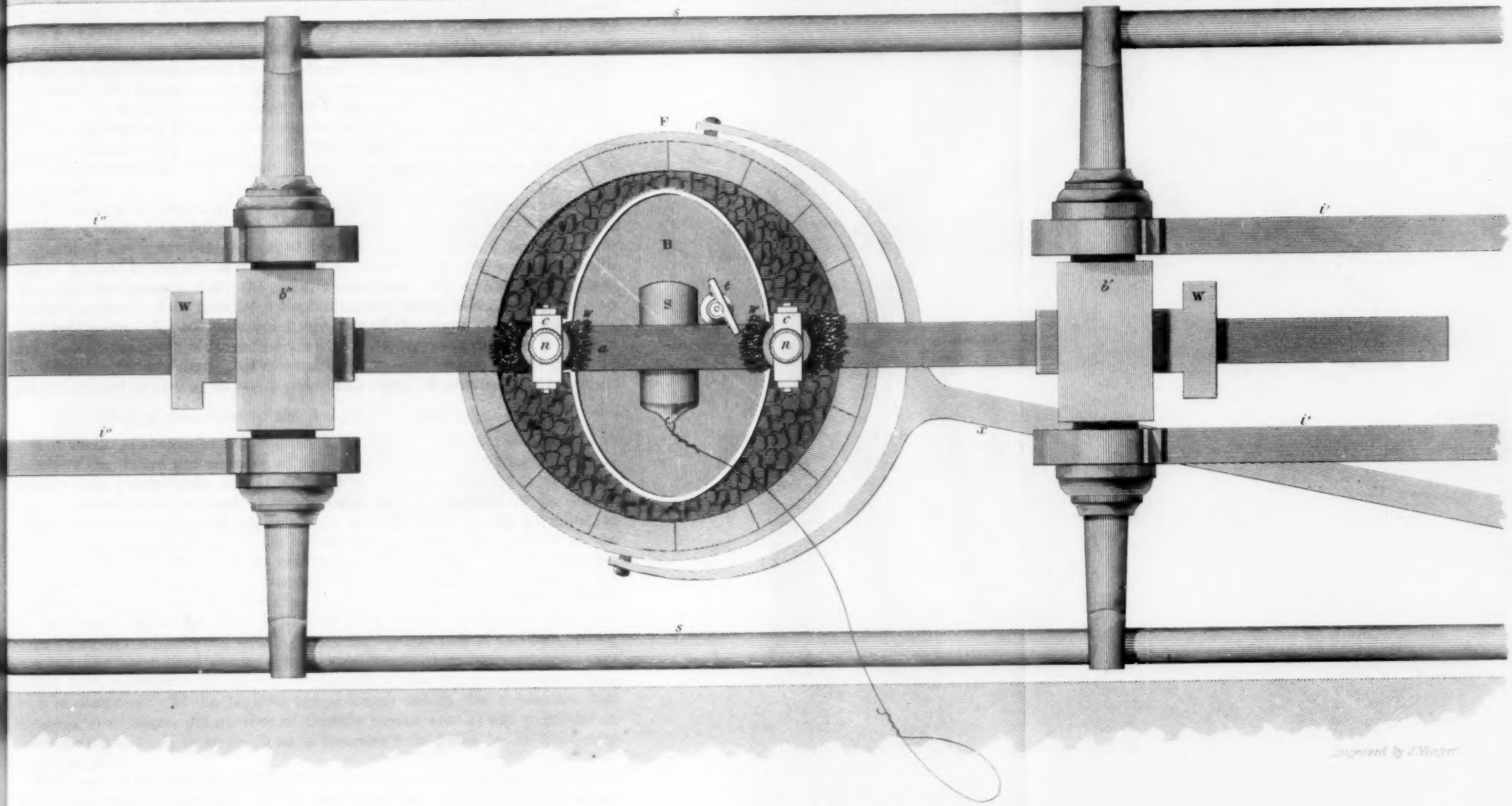
The source of heat for moderate temperatures was either a single or a double-wick spirit lamp, of Dr. MITCHELL's form. When the latter proved inadequate to supply the desired temperature, the furnace of charcoal F was substituted, and, by means of notches *o*, *o*, at its upper rim, it was raised so high as completely to embrace the bath B as represented in plate IV.

### *Standard of High Temperatures.*

The standard of temperatures below the boiling point of mercury was the mercurial thermometer. Above that point the instrument adopted by the committee, was the steam pyrometer described in the *American Journal of Science* vol. xxii. page 96, by Prof. W. R. JOHNSON. At S, plates III. and IV., is the standard piece of wrought iron laid horizontally beneath the bar *a*, and kept in its place by the buoyancy of the mixture of tin and lead, the superior density of the latter metal serving to float the iron, and the higher specific heat of the former, keeping the temperature of the bath more steady than it would have been if lead alone had been employed.

As several improvements have been made in this pyrometer since the date of its first publication, which are conceived to be important in point of accuracy and despatch, it is proper that we should present a view of its structure as used in these experiments, together with a concise statement of the mode in which the latter were conducted.

The instrument is founded on the supposition, that from a mass of water already in ebullition, a weight of vapour may be generated, by immersing a solid, of known weight and capacity for heat, which shall be proportioned to the temperature of such solid above the boiling point of water. In this supposition it is, of course, implied that the specific heat of the solid is constant, or that we allow for its variations;—that during the experiment no heat is received by the water from any other source than the hot solid immersed, and also that vapour ceases to escape, as soon as the solid has been cooled, by vaporization, from the initial temperature, down to that of boiling water. It is further requisite that no heat from the immersed solid be expended in any other way, than the production of vapour by passing from a sensible to a latent state. A convenient apparatus for ascertaining

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which at points so elevated as 13 or 1400 degrees, would not be deemed a very important inaccuracy.

be expended in any other way, than the production of vapour by passing from a sensible to a latent state. A convenient apparatus for ascertaining

the weight of vapour thus expelled by the hot body, used as a standard piece, is another requisite.

In almost all the usual processes of weighing, the time occupied in making an adjustment of the counterpoise, is too considerable to admit the supposition that no loss of vapour from an open vessel of hot water would take place, between the time when the solid attains the boiling point, and that when the equilibrium would be reproduced. To answer the conditions above indicated, the steam pyrometer is constructed in the form represented in plate V. A is a cylindrical boiler, 12 inches high, constructed of two concentric cylinders of tinned sheet iron, between which is a stratum *n*, *n*, half an inch thick, of dry charcoal-dust, (lamp black,) to serve as a non-conductor and preserve the water within, from loss of heat by radiation during the experiment.

The bottom is formed of a single sheet of the same metal connected with the lower edge of the inner concentric cylinder, and rising in the form of a segment of a sphere to the height of $\frac{3}{4}$ of an inch, in order to present an enlarged surface to the action of the lamp L, which keeps the water in ebullition until the moment when the solid is immersed. *t* is a thermometer bent at right angles $\frac{3}{4}$ of an inch from the bulb, and passing along a tube opening into the boiler. A packing around this part of the stem prevents leakage, and the bulb being wholly immersed in the water, serves at all times to indicate its temperature, and particularly to mark the moment when that of the solid has descended so low as to cease generating steam of *atmospheric tension.*

*Mode of ascertaining the weight of vapour expended.*

The mode of suspending the boiler to the beam of the balance, is seen at *m* where the dotted prolongation of the beam B forms a forked curve rather greater than a semicircle, each extremity of the arc *m*, *m*, (Fig. 2.) being turned inward so as to stand at right angles to the direction of the beam; this brings the two bearing edges which support short hooks attached to loops on the opposite sides of the boiler, into the same line parallel to the main axis or knife edge *f*, at the central part of the beam. These parallels are exactly 12 inches apart. The opposite arm of the balance beam is cylindrical, and cut into a fine threaded screw to within an inch and a half of the fulcrum *f*, where the beam is divided for a certain space into two portions (*x x*, fig. 2.) between which passes the upright rod of the supporting stand. The beam used during a considerable part of the experiments contained $150\frac{1}{4}$ threads in one foot of the length of the screw, and was $\frac{1}{8}$ an inch in diameter. At the highest temperatures which the committee had occasion to measure, the number of threads passed over in one experiment, did not exceed $11\frac{1}{2\,0}$ or so much as to measure from 1100, to 1200 degrees of temperature.

By a careful measurement of different numbers of threads, selected at various parts of the screw-arm, (which was 16 inches long) it was ascertained that, though at the two extremities, the threads differed slightly from their mean length, yet at the middle portion, where the revolving counterpoise P is represented in the figure, no appreciable difference could be detected, and as this was the part always occupied by the weight, the instrumental error from this source may be considered altogether unimportant. In fact the extremes of the variation just referred to taken most unfavourably, could not have in the highest temperatures, amounted to more than 7 degrees Fah., which at points so elevated as 13 or 1400 degrees, would not be deemed a very important inaccuracy.

But even this was avoided by occupying that part of the screw where the threads were of equal length; and by making an adjustment of the balance and weighing any given body placed on the boiler, with the counterpoise in different parts of the range selected for the experiments, it was easy to verify the accuracy of the measurements and determine precisely the error, if any had existed. But this method when tried, only served to confirm the result of the other.

*The revolving counterpoise.*

On the screw already described, was placed a revolving counterpoise P, which, together with its index I, placed on a neck projecting beyond the base of the cylinder, weighed 10517 grains; consequently, as each thread of the screw measured 0.07872 of an inch, the motion of the counterpoise over one thread was equivalent in effect to a weight of 100 grains applied at that end of the beam where the boiler is suspended, or $\frac{1}{1\,0\,0}$ part of a revolution marked a difference of one grain in the weight of water in A.*

* The method used in determining, by calculation, the true adjustment of parts and the graduation of the scale of the steam pyrometer is equally applicable, whatever may be the length of the weighing beam, or of the threads of the screw, and whatever the nature of the material employed for a standard piece, the latent heat of vapour, the kind of liquid from which it is produced, or the scale of thermometer to which we refer the indications, marked on the revolving counterpoise.

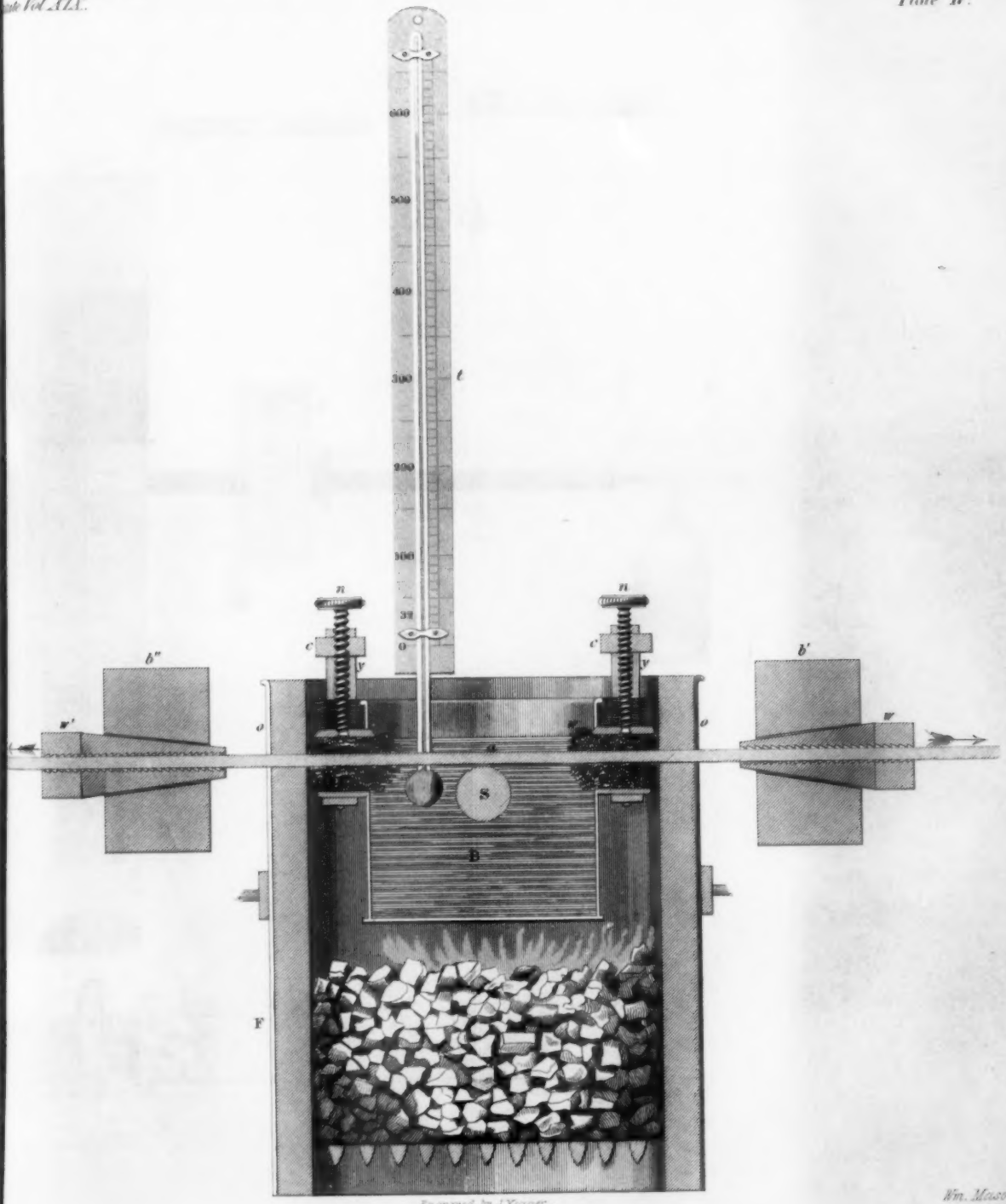
Thus if $L$ be the length of the arm from $f$ to $m$ where the boiler is suspended, and $n$=the number of threads of screw on an equal length of the opposite arm; then will $\frac{L}{n}$=the length of a thread.

Putting $P$=the weight of the counterpoise,

and $v$=the weight of vapour which must escape in order that an equilibrium, destroyed by its loss, should be restored by making $P$ move one revolution, that is one thread nearer to $f$, we shall have $\frac{L}{n} : L :: v : P$ or $\frac{PL}{n}=Lv$; whence $v=\frac{P}{n}$.

This may be termed the *mechanical relation* of the instrument to the vapour produced.

To determine the *physical action* of the standard piece, if $z$ be supposed=its specific heat; $l$=the latent heat of vapour from the liquid at its boiling point; $i$=the weight of the standard piece (expressed in the same denomination as that of $P$); $t$=the number of degrees to be placed on the circumference of the revolving weight; $P$=the degrees belonging to the same scale as those in which $l$ is expressed; and $v$=(as before,) the weight of vapour counterpoised by a single revolution of $P$; then the efficient cause of vaporization while the standard piece cools through $t$ degrees, will be represented by $itz$, and the *effect* produced must be expressed by $vl$; Hence is derived the equation $lv=itz$, or $v=\frac{itz}{l}$. Comparing this value of $v$ with that obtained above, we get $\frac{P}{n}=\frac{itz}{l}$. Hence the weight of the standard piece $=i=\frac{Pl}{ntz}$, and the five following formulas will give *either one* of the other quantities, when the rest are assigned, viz. $P=\frac{nitz}{l}$; $z=\frac{Pl}{nit}$; $n=\frac{Pl}{itz}$; $t=\frac{Pl}{niz}$, and $l=\frac{nitz}{P}$. In practice it was found most convenient to make $t=100°$ Fah. But by assuming $t$ equal to the distance *between the freezing and the boiling point of water* under mean atmospheric pressure, a single standard piece would be sufficient to render the instrument universal in its indications. The curved surface of the revolving weight would only require to be divided into as many separate bands as there were different scales to be placed upon it, and graduating each band into as many equal parts as the particular scale comprehends degrees between the two

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Wm. Mason Del.

# STEAM PYROMETER.



Fig. 2.

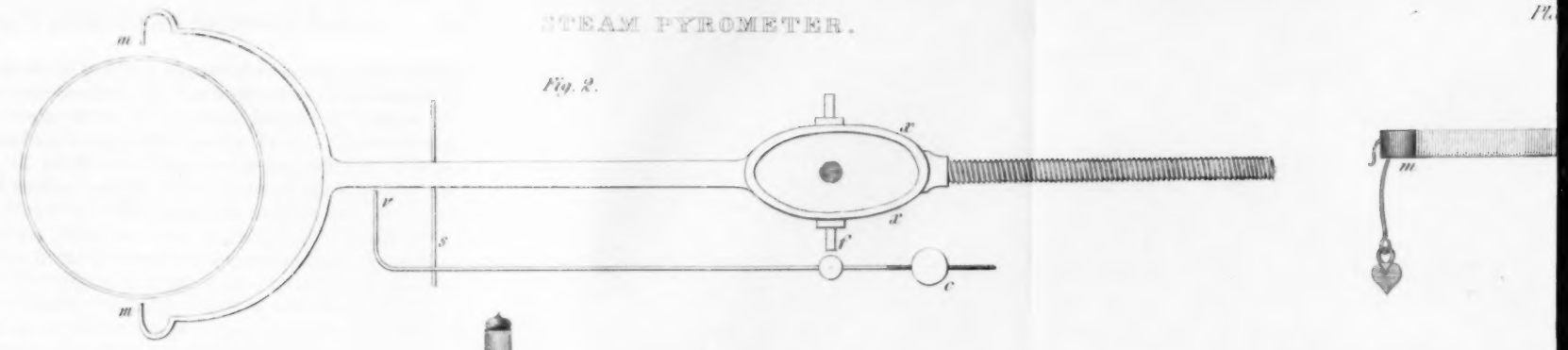
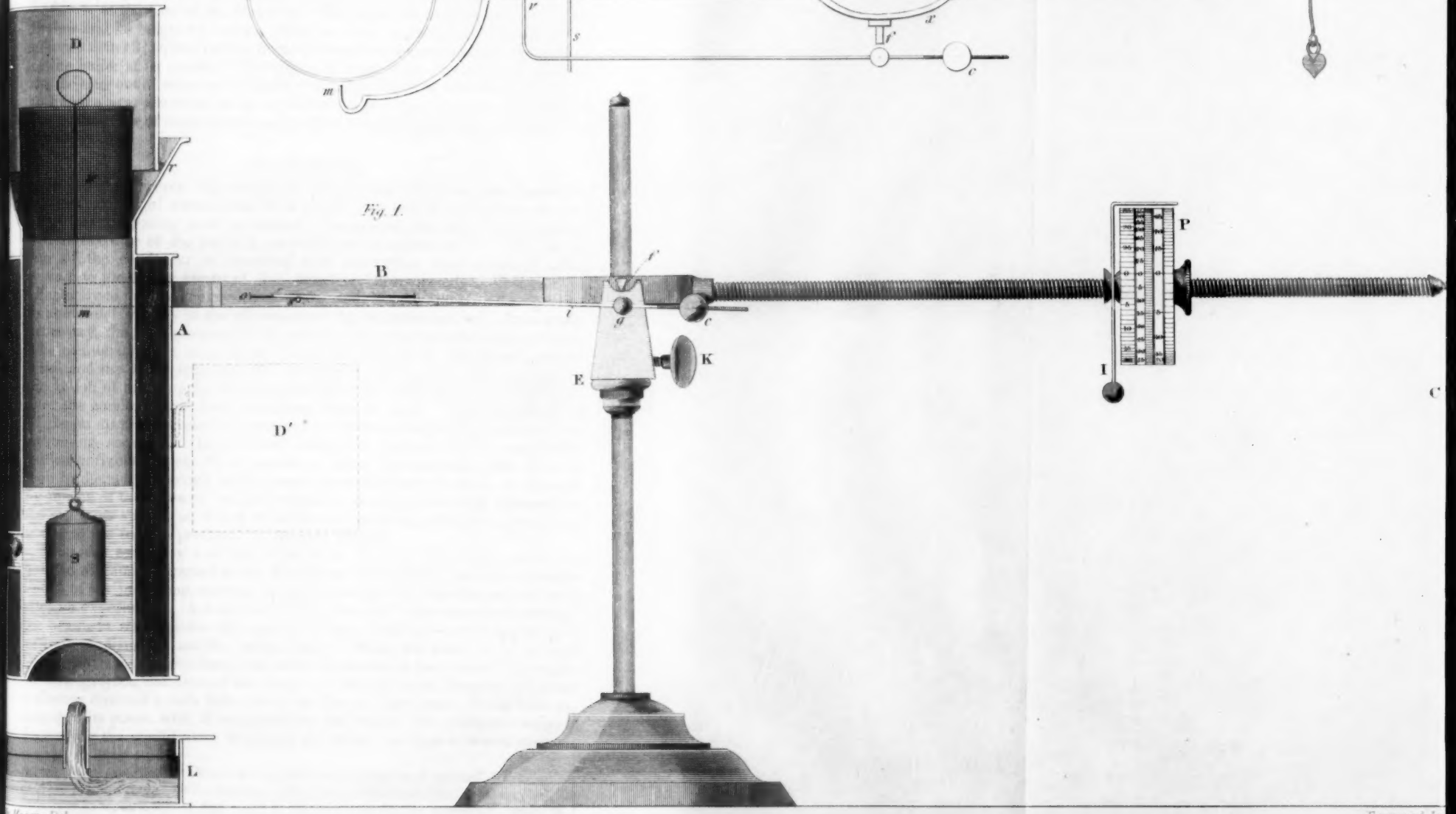
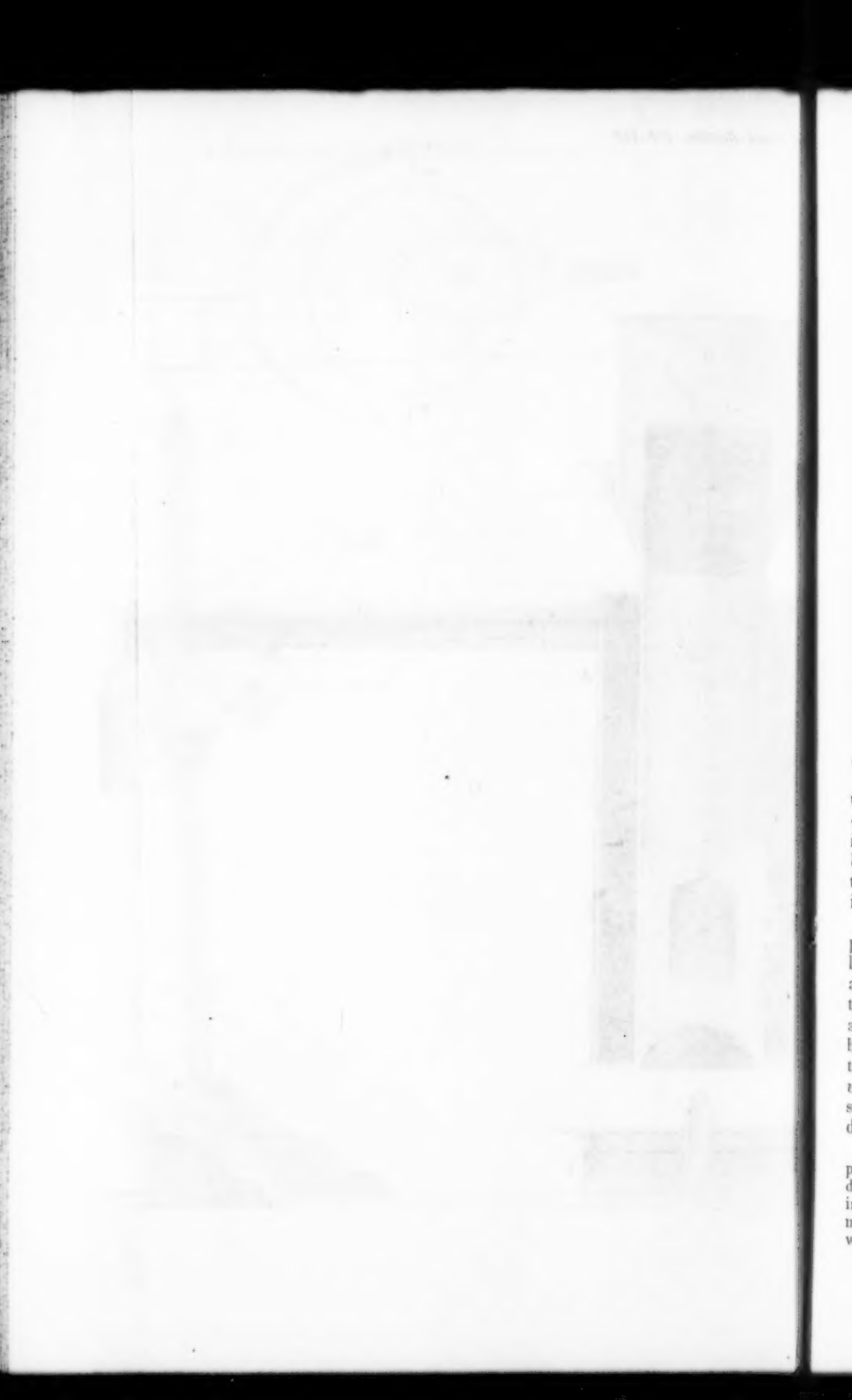



Fig. 1.





The standard piece employed to produce vapour after having been heated in the bath of melted metal surrounding the bar under trial, was formed of wrought iron of the figure seen at S, its greatest length $2\frac{3}{4}$ inches, its diameter one and $\frac{1}{16}$ inch and its weight 6336 grains Troy. This was suspended by an iron wire $\frac{1}{50}$ of an inch in diameter to the centre of a wire-gauze cap *w*, the lower and smaller end of which, entered the mouth of the boiler A, at the base of the funnel *r*. The upper diameter of this cap is $2\frac{1}{2}$ inches and its height $2\frac{3}{4}$ inches, giving an area, including the top and sides, of more than $13\frac{1}{2}$ square inches, or more than three times as much as the section of the boiler at its mouth. The object of employing this cap is to prevent the dashing out of water by ebullition—an effect which is, however, only liable to happen near the close of an experiment when the iron has descended to the temperature of *maximum vaporization*,* and when the boiler contains too much water.

*The Condenser.*

In order to prevent all escape of vapour after ebullition has ceased, a cylindrical cap of tinned iron D, is placed over that of wire gauze, the instant that the boiling point is attained. In general, this cap is kept suspended at one side of the boiler A, as exhibited in outline at D′. The lower rim of the condenser is furnished with an exterior welt or hem of silk, sewed to the tin by means of fine punctures near its edge. This serves effectually to prevent the escape of steam, and, besides allowing the operator to attend deliberately to the adjustment of the counterpoise, will admit, when necessary, the postponement of this process for a considerable length of time. The counterweight *c*, is to balance the standard piece S, with its suspending wire, and the wire-gauze cap W. As long as the water is kept boiling by the action of the lamp L, C is removed from the beam and is replaced only after the condenser has been transferred from D′ to D. The support E of the beam may be elevated or depressed on its sustaining rod by means of the tightening screw K. Immediately below the fulcrum *f*, is a small hole drilled horizontally into E, to receive a brass tap carrying a ball $\frac{3}{8}$ of an inch in diameter, through which passes the small index-wire *i*, so adjusted by means of the screwed counter weight *c*, as to be accurately balanced on the tap *g*, as an axis on which it turns with no other resistance than what is due to the friction produced by its own weight.

Near the extremity *v* of this wire, it is bent at right angles, and the pointed extremity directed to the side of the beam where, at *o*, is a straight line $\frac{3}{4}$ of an inch long, serving to guide the eye in reproducing the level after an experiment. A little below this line, is a transverse hole through the beam, in which slides the register *s* (Figs. 1 and 2,)—a wire about $\frac{1}{16}$ of an inch in diameter, and $2\frac{1}{2}$ inches long. While the water in A is kept boiling by means of the lamp, the boiler continues to rise, and as the register now projects out beyond the index *i*, it lifts the latter, keeping the point *v* always directed a very little above the line *o*. But when W has been inserted in its place, with S suspended in the water, the additional weight, destroying the equilibrium, depresses the boiler, the base of which rests on

points above mentioned. Thus we should have on the band marked Reaumer, 80 degrees; Centigrade, 100°; Delisle, 150°; and Fahrenheit 180.° It may not be improper to remark that in applying the above formulas, the numerical value of *l* must also vary with the thermometrical scale. Thus if for Fah. it be 1037° it will be for Centigrade, $576\frac{1}{9}$; for Delisle, $863\frac{4}{9}$, and for Reaumer $460\frac{8}{9}$.

*See Amer. Journal of Science, vol. 21, p. 304.

the flat surface of the lamp L, the concavity in the bottom serving as an extinguisher to the flame. The index *i*, is, in the mean, time left at the level attained by the register at the moment before the immersion. While ebullition is proceeding, the operator pushes back the register so as to project but little from the interior side of the beam; then observing the thermometer *t*, takes the condenser from the position D′, and, at the instant the ebullition ceases, covers the boiler with it, as at D, letting the standard piece remain in place; and having attached the counterpoise C, proceeds to bring down the boiler end of the beam, (which at first rises above the index *i*,) by causing P to revolve in the direction towards *f*.

The number of revolutions being counted so many hundreds of degrees, he has only to add to their number 212°, in order to obtain at once the temperature by Fahrenheit's scale.

As both the latent heat of vapour and the specific heat of iron enter into the calculation, in constructing the steam pyrometer, and as on both these points considerable discrepancy prevailed among writers who had treated of these subjects, it was thought important to attempt a direct solution of the question as presented in the particular case of this investigation.

Two methods offered themselves, of verifying the calculations respecting the instrument. The first was, to heat the standard piece to any known temperature above 212°, and in that state plunging it into the boiling water to ascertain whether the amount of water vaporized weighed as many parts measured by hundredths of a revolution of C, as the standard piece had been heated in degrees above the boiling point.

This method being the most direct, was first resorted to by the committee.

As the standard piece S, was at first made one or two hundred grains heavier than was supposed to be necessary, trial was made in the way just indicated, and as an excess of vapour was found to have been obtained, the standard piece was proportionally reduced in weight to that which has been already stated.

The other method consisted in determining separately by direct experiment, both the latent heat of vapour, and the specific heat of the standard piece. The researches on these subjects were made in the manner and with apparatus described below.

### *Specific heat of iron.*

In determining the specific heat of the standard piece of the steam pyrometer it was deemed adviseable to employ processes somewhat independent of each other, and especially to vary the circumstances of the experiments, so that if possible the discordances on this subject might be reconciled, or at least referred to their probable origin. The first step was to ascertain the specific heat of the standard piece from 212° to the ordinary temperature of the atmosphere.

### *Bath for heating the standard piece.*

The apparatus for this purpose is represented in plates VI. and VII. In plate VI. is seen a vertical section of the apparatus in which the iron standard piece S was heated. W is a cast iron vessel in the form of a frustum of a cone, 12 inches high, 7 inches in diameter at top, and 5 at the bottom; the upper edge being furnished with a flanch to match a corresponding flanch on a cover D, which was turned to fit it, and to form with it a steam tight joint as at *f*.*f*.. In the central part of this cover is the mouth of another vessel or tube M, $2\frac{1}{2}$ inches in diameter, the bottom of which is about $\frac{1}{2}$ an inch

above the bottom of W. The space between the outside of the tube M and the inside of W, is nearly filled with water, as seen at *w*, *w*, introduced by an aperture ordinarily closed by the iron stopper P. The interior of M is filled to about the level *m*, *m*, with mercury.

In the cover D on the side opposite to P, is another aperture into which is fitted by grinding, an iron tube G, to receive and convey away to a water vessel I, the excess of vapour generated in W. The vessel thus constructed is placed in a circular opening in a sheet iron plate, B B, 14 inches square, which rests on two guide rods R, R, of the frame of the machine. (Plate, 1.)

F is the furnace already described, as applied to the purpose of heating the bars of iron. X is a sheet iron cylindrical case, $\frac{1}{8}$ of an inch thick, open at both ends, and having along one side, a slit *s s*, $\frac{1}{16}$ of an inch wide left for the purpose of permitting the wire *n*, by which the standard piece S is suspended, to be introduced or withdrawn laterally, while the loop at its top is held by one hand of the operator; and by the other, the handle Y. The rod which carries this handle is fastened by rivetting to the inside of the case K, and below the rivets the point is turned inward toward the centre of the case, preventing the iron cylinder S from rising above that point. This gives the operator entire command of the latter, notwithstanding the buoyancy of the mercury.

The thermometer T, graduated above the boiling point of water, was placed with its bulb on a level with the centre of S.

By raising or lowering the furnace F, the ebullition was maintained at a nearly uniform rate during the time of several consecutive experiments.

When the mercury in T was found to be stationary at 212°, the shield K was withdrawn from the mercurial bath; the operator held Y in one hand, while the other supported the wire *n*; and in this manner without allowing S to come in contact with the air, conveyed it to the mouth of the water vessel of the cooling apparatus, where K was held in a vertical position, and the wire quickly lowered till the standard piece was immersed, when the shield was immediately removed, the wire escaping through the slit *s s*.

*The cooling apparatus.*

The arrangement of parts in the cooling apparatus, is seen in plate VII., where A is the cylindrical containing vessel, filled with water to such a height as to be completely full, when the standard piece S, and the bulb of thermometer *t* are immersed.

B is a cylindrical vessel of tinned iron, 14½ inches high, and 9 inches in diameter, to which is adapted the cover D of the same material, having in the middle a circular aperture *a a*, 3 inches in diameter, for receiving the thermometer *t*, and the standard piece S; allowing likewise sufficient space to move the suspending wire and thermometer. Another aperture through D, near its circumference, admits the lower part of the thermometer *i*, and an opening near the bottom of B, receives the bulb of the thermometer *l*.

The thermometer O was suspended just without the vessel B, to mark the temperature of the room. C is a support for the water vessel A, formed of a cylindrical block of charcoal, 4 inches high.

The method of adjusting the weight of water in A, in this series of experiments, was the same as that subsequently described in the experiments on the latent heat of vapour, except, that in the present case, no process of weighing was required, after the heating had been performed.

The exact adjustment of the quantity of water to be used in every repetition of a given series, was made by means of a tube, of small dimensions, open

at both ends; by the aid of which it was easy to add or to remove minute quantities of liquid to render the balance true.

*Thermometer in the Water Vessel.*

The most important of the thermometers used in this part of the investigation was that marked *t*, but which was in fact the thermometer A, elsewhere referred to, the bulb of which was $7\frac{1}{4}$ inches long, intended to reach from the top to the bottom of the liquid, and which, it actually did in some of the containing vessels, with which it was used. Its diameter was about $\frac{3}{4}$ of an inch. The glass constituting the bulb of this thermometer weighed 433.85 grains, as ascertained by actual weighing, after the instrument had been broken. It was filled after the elongated bulb had been joined to its stem, and the separate weight of these ascertained. The mercury precisely filled the bulb alone at 32°, and the weight of mercury required for this purpose was found to be 4682 grains. As most of the experiments with this instrument were made with an initial temperature about 62°, it has not been deemed necessary to make more than one correction for the quantity of mercury expelled from the bulb, or excluded from the influence of the water vessel. At 62° the bulb must have held, by calculation,* 4670 grains of mercury, which by a mean of several determinations already published, possesses a specific heat of .0327, and gives an equivalent in grains of water, of 152.7.

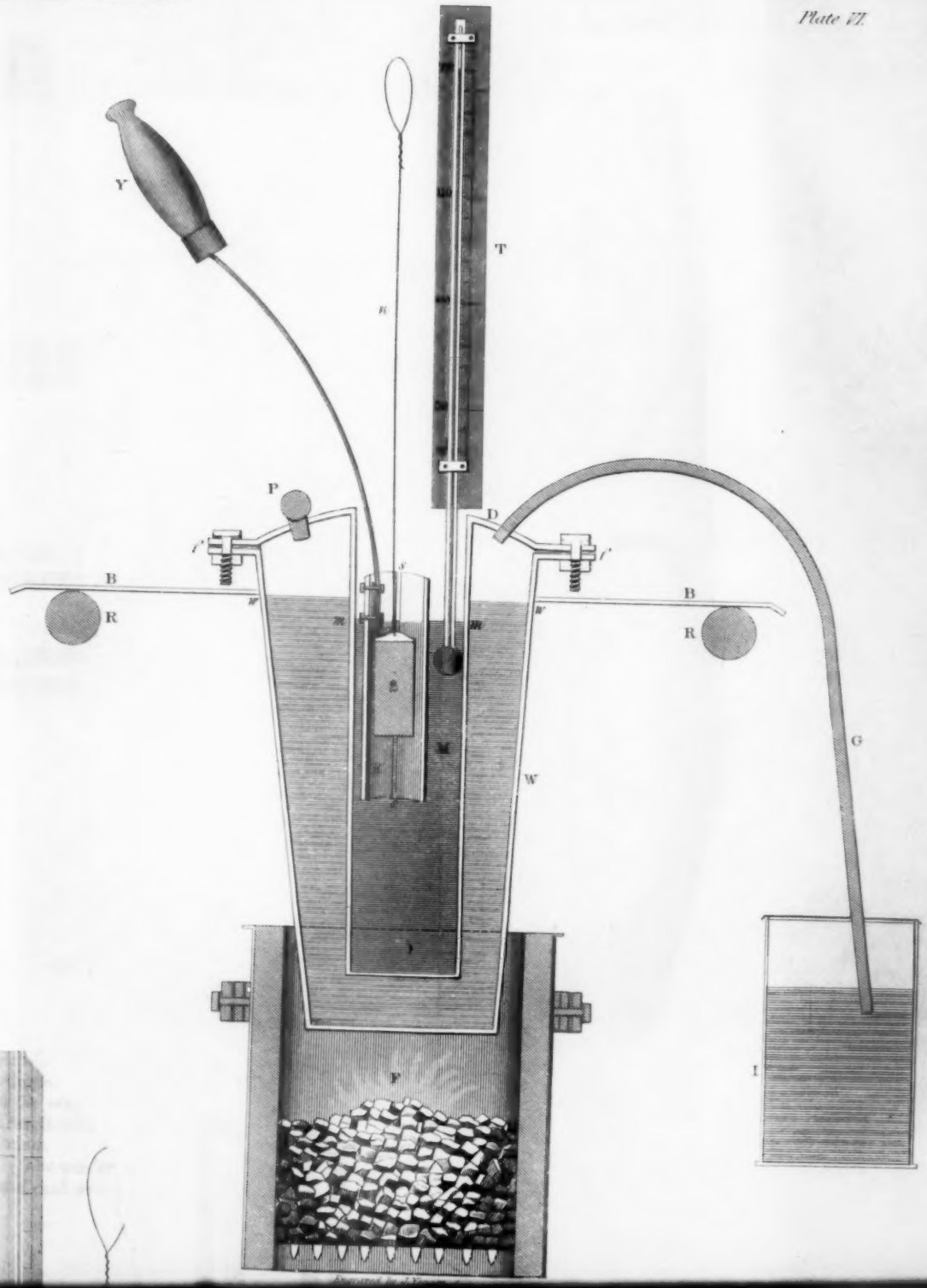
When this thermometer was used in connexion with a containing vessel of glass, the weight of its bulb was added to that of the vessel; and in other cases, the specific heat attributed to it, was that obtained by means of several trials of it with glasses of different thicknesses instituted with a view to determine the effect of that material, towards cooling the heated body or standard piece. The specific heat thus found was .10036, according to which the bulb would be equivalent to 43.45 grains of water. The length of the scale of this thermometer was 37 inches, and the graduation extended from 34° to 74°; so that each degree was nearly $\frac{37}{40}$ of an inch in length and the degrees were divided each into 50 parts, each part being of such magnitude that the eye could, when necessary, easily subdivide and read them into hundredths.

The graduation of this thermometer was obtained by direct comparison with a well tried standard instrument, the degrees of which were about $\frac{1}{4}$ of an inch in length. For this purpose, the bulbs of both were immersed in a large quantity of water contained in a Hessian crucible, surrounded by another of black lead; thus affording a combined mass which changed its temperature with extreme slowness, and enabled us to mark with deliberation and accuracy every degree on the long scale, after having for some time agitated the two in contact with each other and tempered the water to the point required.

The general mode of operating with the apparatus, plate VII., was, after giving the water vessel and thermometer *t*, a temperature a few degress below that of the surrounding air, to take simultaneous observations of all the thermometers which were recorded by one assistant, while another person

* Petit and Dulong, found the expansion of *mercury in glass* between 32° and 212,° to be $\frac{1}{63.8}$ consequently its expansion for 1° $\frac{1}{180\times 63.8}=\frac{1}{11484}$, and for $(62°-32°)=30°$, it will be $\frac{30}{11484}$ of its bulk at 32°. But $4682\times\frac{30}{11484}=12.2$ grains and $4682-12=4670$ as above stated.

Plate 17.



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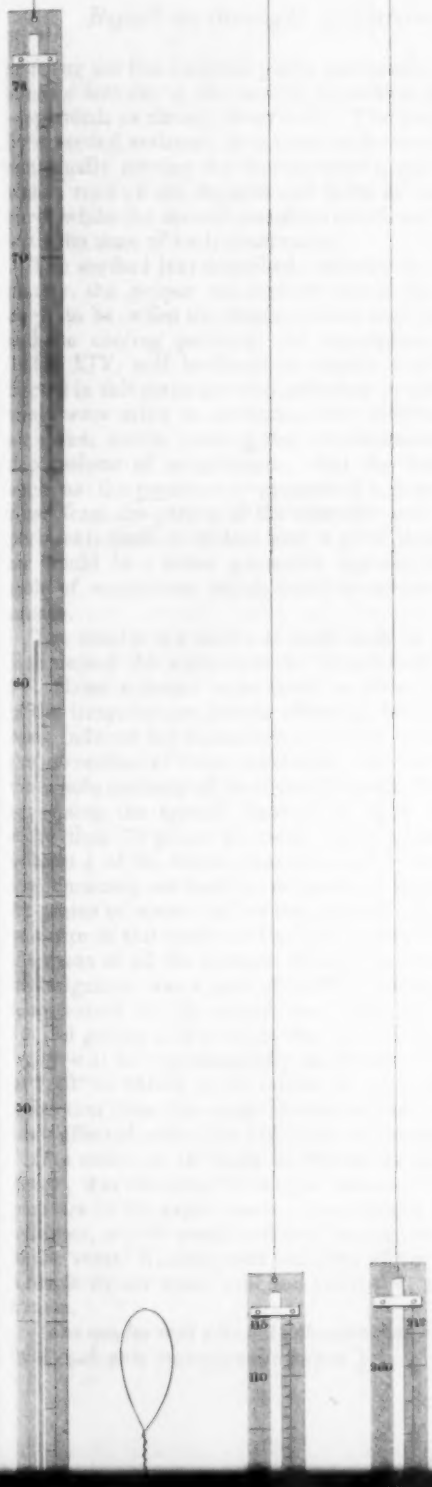
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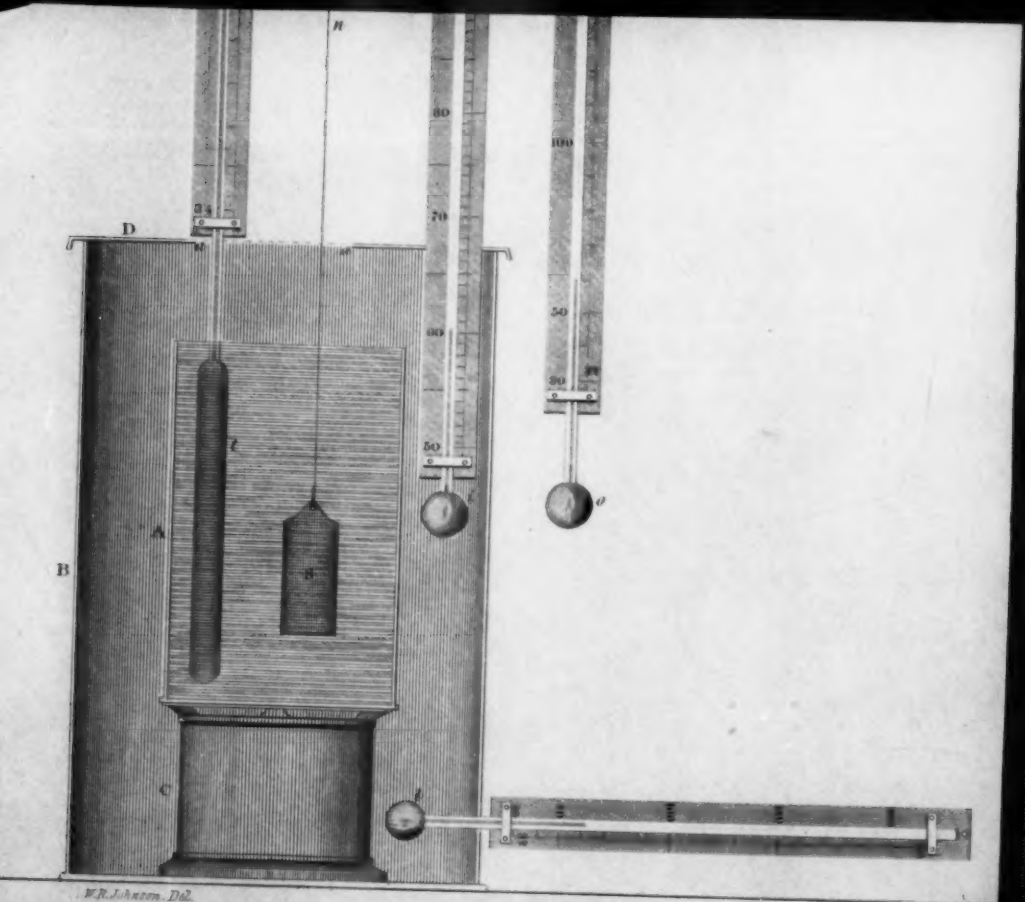
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W.R. Johnson. Del.
Engraved by J. Yeager.

bringing the hot standard piece, surrounded by its shield, from a distance of about 4 feet out of the heating apparatus (Plate VI.) immersed and held it suspended, as already described. The moment of immersion was observed by a second assistant, on a time-keeper marking seconds. The manipulator continually moving the thermometer *t*, and the standard-piece about in the water, read off the degrees and parts as successively attained by the mercury, while the second asssistant noted, and the first recorded them, together with the time of each observation.

The method just described, afforded the means of determining approximately, the proper temperature below that of the air, at which the water ought to be, when the standard-piece was immersed, in order that the heating and the cooling power of the atmosphere should be equal to each other. Table XIV. will be found to contain a synopsis of the experiments conducted in this mannner with reference to different containing vessels. Some trials were made to ascertain, with different vessels, the rate at which the air alone, would, under given circumstances, produce certain elevations or depressions of temperature. But the interference of extraneous causes, such as the presence or absence of a stove in the apartment, the heat derived from the person of the observer, and others near the scene of the experiment, made it evident that a good defence against the influence of the air would be a better guarantee against error, from that source, than any table of corrections which could be constructed amidst so many modifying causes.

The results of a series of trials made in part without employing the vessel B to defend the water from the air and from radiation, are exhibited in Table IV. Some attempts were made, as above referred to, towards the correction of the irregularities therein observed; but the uncertainty attending the process, induced the committee to prefer, when practicable, the *prevention*, to the *correction* of these anomalies. As the vessel B held 924½ cubic inches, the whole quantity of air it could contain did not exceed 277½ grains; which, supposing the specific heat of air to be .26, would not be equivalent to more than 72 grains of water, but as a considerable portion, amounting to at least ⅓ of the whole, was occupied by the water vessel and its support, the remaining air could in no instance have been equivalent to more than 62 grains of water, and as the greatest change which occurred in the temperature of this portion of air during any experiment, was but 1.7°, and as the mean of all the changes of this kind observed during the progress of the investigation, was a gain of 0.325°, while the correspondent mean gain of temperature in the water was 7.26°, and the mean weight of the latter 13.100 grains, it is evident that the relative influence of the air and of the water will be represented by 62 grains × 0.325° = 20.15 and 13100 grains × 7.26° = 95106, or the former is $\frac{1}{4720}$ part of the latter, from which it appears that from this cause the expression for the specific heat could not have been affected under the fifth place of decimals.

In a series of 13 trials in which the water, amounting to about 40,000 grains, was contained in copper vessels, (Table VIII.) and the rise of temperature in the same was at a mean about 2.5° the air gained about .292 of a degree, which would indicate that the cooling power of the air confined in the vessel B, compared with that of the water in A was but as 1 to 5550, a result which would still less affect the general correctness of the determination.

[*The reader will please to observe that many of the following Tables extend each over two opposite pages.*]

**TABLE IV.** *Experiments to determine the specific heat of the wrought iron standard piece used in experiments with the steam pyrometer employed in this investigation, the water being contained in a thin glass cylindrical jar, weighing* 3325 *grains, and*

| No. of experiment. | Date. | Temperature. | Temperature of the water at the beginning. | Temperature of the water at the end. | Gain of temperature by the water. | Loss of temperature by the iron. | Time taken up by the experiment. | Weight of water in the jar. | Equivalent of vessel in grs. of water. | Equivalent of thermometer in water. |
|---|---|---|---|---|---|---|---|---|---|---|
| | | ° | ° | ° | ° | ° | | grs. | grs. | grs. |
| 1 | 1834. Nov. 22. | 69. | 64.5 | 69.8 | 5.3 | 142.2 | 480″ | 19177.8 | 339 | 140. |
| 2 | Dec. 6. | 65.5 | 59.5 | 64.8 | 5.3 | 147.2 | 400 | 19788.1 | 329 | 143.3 |
| 3 | " | 69. | 61.2 | 66.5 | 5.3 | 145.5 | 300 | 19788.1 | 339 | 143.3 |
| 4 | " | 70.5 | 64.15 | 69.2 | 5.05 | 142.8 | 210 | 19788.1 | 339 | 143.3 |
| 5 | " | 73.5 | 58.4 | 63.9 | 5.5 | 148.3 | 180 | 19788.1 | 339 | 143.3 |
| 6 | Dec. 8. | 74.5 | 65.1 | 70.2 | 5.1 | 141.8 | 200 | 19788.1 | 339 | 143.3 |
| | | | | correc. 69.76 | correc. 4.66 | correc. 142.24 | | | | |
| 7 | " | 72.5 | 71.6 | 76.6 | 5.1 | 135.4 | 200 | 19788.1 | 339 | 143.3 |
| 8 | " | 73.5 | 69.15 | 74.4 | 5.25 | 137.6 | 240 | 19788.1 | 339 | 143.3 |
| | | | | correc. 74.02 | correc. 4.87 | correc. 137.98 | | | | |
| 9 | " | 72. | 64.8 | 69.9 | 5.1 | 142.1 | 210 | 19788.1 | 339 | 143.3 |
| 10 | " | 75. | 70.95 | 75.8 | 4.85 | 136.2 | 210 | 19788.1 | 339 | 143.3 |
| 11 | " | 76. | 70. | 75.1 | 5.1 | 136.9 | 240 | 19788.1 | 339 | 143.3 |
| 12 | Dec. 29. | 62. | 61.9 | 67. | 5.1 | 145. | 240 | 20050. | 339 | 43.4 |
| 13 | " | 65. | 59.8 | 64.8 | 5. | 147.2 | 180 | 20050. | 339 | 43.4 |
| 14 | 1835. Jan. 3. | 65. | 60. | 65. | 5. | 147. | 180 | 20050. | 339 | 43.4 |
| 15 | " | 66. | 59.75 | 64.55 | 4.8 | 147.45 | 180 | 20050. | 339 | 43.4 |
| 16 | " | 66. | 59.6 | 64.50 | 4.9 | 147.5 | 180 | 20050. | 339 | 43.4 |
| 17 | " | 65. | 59.6 | 64.40 | 4.8 | 147.6 | 240 | 20050. | 339 | 43.4 |
| 18 | Jan. 10. | 63. | 65.2 | 69.8 | 4.6 | 142.2 | 152 | 20050. | 339 | 43.4 |
| 19 | " | 62.2 | 65.2 | 69.8 | 4.6 | 142.2 | 154 | 20050. | 339 | 43.4 |
| 20 | Jan. 17. | 71. | 66. | 70.7 | 4.7 | 141.3 | 272 | 20050. | 339 | 43.4 |
| 21 | " | 68. | 63.3 | 68.15 | 4.85 | 143.85 | 194 | 20050. | 339 | 43.4 |
| 22 | " | 61.9 | 54.5 | 59.8 | 5.3 | 152.2 | 119 | 20050, | 339 | 43.4 |
| 23 | " | 63.5 | 60. | 64.9 | 4.9 | 147.1 | 149 | 20050. | 339 | 43.4 |
| 24 | Jan. 24. | 63.5 | 64.9 | 69.5 | 4.6 | 142.5 | 96 | 20050. | 339 | 43.4 |
| 25 | " | 71. | 67.1 | 71.8 | 4.7 | 140.2 | 145 | 20050. | 339 | 43.4 |
| 26 | " | 71. | 67.1 | 71.8 | 4.7 | 140.2 | 153 | 20050. | 339 | 43.4 |

[TABLE IV.] *capable of containing, in addition to the thermometer and standard piece, about* 20,000 *grains of water. The iron was heated in a bath of mercury surrounded by boiling water, giving it a temperature of* 212° *at the time of each immersion.*

| Weight of water and equivalent of glass and thermom. | Loss of temperature × weight of metal. | Gain of temperature × weight of water. | Specific heat by the uncorrected data. | REMARKS. |
|---|---|---|---|---|
| 19656.8 | 853200 | 104181.04 | .12210 | Using for specific heat of glass, the result obtained by 10 comparisons, viz. .101911, we have the equivalent of the *container* in this series=339 grains. |
| 20270.4 | 883200 | 107433.12 | .12164 | Began too low. |
| 20270.4 | 873000 | 107433.12 | .12306 | Water gained heat from the air the whole time of this experiment. |
| 20270.4 | 856800 | 102365.52 | .11947 | Final temperature much too low. |
| 20270.4 | 889800 | 111487.2 | .12529 | Do. much more so. |
| 20270.4 | 850800 | 103379.04 | .12150 | The correction here made is from observing that ,at the initial temperature 45″ were required for the air to heat the water .1 of a degree. This gives sp. ht.=11.068. |
| 20270.4 | 812400 | 101352. | .12475 | Exposed to radiation from the stove, gained .1° in 40,″ when air was 73, water 70.4. Corrected result =.11068. |
| 20270.4 | 825600 | 106420.2 | .12890 | Gained from the air, and from radiation, .05° in 25″, or 0.38° in 240″, leaving the corrected gain 4.87. Corrected result =.11924. |
| 20270.4 | 852600 | 103379.04 | .12124 | Began and ended below the temperature of the room; result considerably too high. |
| 20270.4 | 817200 | 983114.4 | .12018 | Ended very near the temperature of the room; result too high. |
| 20270.4 | 821400 | 103579.04 | .12549 | Ended below the temperature of the room. |
| 20432.4 | 870000 | 104205.24 | .11977 | Began at the temperature of the room—stove in action. |
| 20432.4 | 883200 | 102162. | .11567 | Ended below temp. of room; result too high. |
| | | | | Mean of 13 preceding results=.123004. |
| 20432.4 | 882000 | 102162. | .11583 | Ended at temp. of room. Now shielded the water vessel with a conical tin cover, with an opening to admit the thermometer. |
| 20432.4 | 884700 | 98075.52 | .11081 | Shielded as above. |
| 20432.4 | 885000 | 100118.76 | .11313 | Ended below temp. of the external air in room, but the shield was probably lower. |
| 20432.4 | 885600 | 98075.52 | .11074 | Do. do. |
| 20423.4 | 853200 | 93989.04 | .11016 | Began 2.2° and ended 6.8° above the temperature of the air; result too low. |
| 20423.4 | 853200 | 93989.04 | .11016 | Began 3° and ended 7.6° above the air; too low, as before. |
| 20432.4 | 847800 | 96032.28 | .11327 | Air in shield probably lower than without. |
| 20432.4 | 863100 | 99197.14 | .11493 | Began 4.7° *below*, & ended 8.15° ab. the air. |
| 20432.4 | 913200 | 108291.72 | .11858 | Ended 2.1° below the temp. of the air. Result consequently much too high. |
| 20432.4 | 882600 | 100118.76 | .11343 | Begun 3.5° below, and ended 1.4° above the air; a very fair experiment. |
| 20432.4 | 855000 | 93989.04 | .10991 | Began 1.4° and ended 6° above the air; result much too low. |
| 20432.4 | 842400 | 96032.8 | .11399 | Began 3.9° below, and ended 0.8° above the air, received heat a little too long; result, a trifle too high. |
| 20432.4 | 842400 | 96032.28 | .11399 | This experiment conformed in conditions precisely to the preceding. and the result is reproduced. [Mean of last 13=.11294.] |

## TABLE V.

*Experiments to determine the specific heat of the iron Standard-piece used in Experiments with the Steam Pyrometer employed in this investigation. The heating being performed in a bath of mercury surrounded with boiling water, and the cooling in a*

| No. of Experim't. | DATE. | Temp. of the air in the room at the beginning. | Temp. of the air at the end of the experiment. | Temp. of air inside of shield at beginning. | Temperature of the air inside at the end. | Evap. point of air | Temperature of the water at the commencement. | Temperature of the water at the end. | Temperature gained by the water. | Temperature lost by the iron. | Time elapsed during the exper't. | Weight of water used. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1835. | | | | | | | | | | | |
| 1 | Feb. 28, | 58.75 | 59. | | | 48 | 52.62 | 58.105 | 5.495 | 153.895 | 313″ | 16728.75 |
| 2 | " | 57. | 58.25 | | | 48 | 56.09 | 61.71 | 5.62 | 150.29 | 260 | 16728.75 |
| 3 | " | 57.75 | — | | | 48 | 52.33 | 57.83 | 5.50 | 154.17 | 319 | 16728.75 |
| 4 | " | 53. | 55.5 | | | 48 | 49.35 | 55.28 | 5.93 | 156.72 | 135 | 16728.75 |
| 5 | Apl. 7, | 67.1 | 68.5 | | | 49 | 63.50 | 68.94 | 5.44 | 143.06 | 177 | 16494.5 |
| 6 | " | 67.1 | 67.7 | | | 49 | 63.52 | 68.97 | 5.45 | 143.03 | unc | 16494.5 |
| 7 | " | 67.15 | 66.70 | | | 50 | 63.50 | 68.90 | 5.4 | 143.1 | unc | 16494.5 |
| 8 | " | 67.1 | 67.58 | | | 50 | 63.50 | 68.90 | 5.4 | 143.1 | | 16494.5 |
| 9 | Apl. 18, | 58. | 58. | 55. | 55.25 | 51 | 53.3 | 59.09 | 5.79 | 152.91 | | 16494.5 |
| 10 | " | 60. | 60.5 | 56. | 56.5 | 51 | 52.46 | 58.34 | 5.88 | 153.66 | | 16494.5 |
| 11 | " | 62. | 62. | 58.25 | 58.5 | 51 | 51.3 | 57.28 | 5.98 | 154.72 | | 16494.5 |
| 12 | " | 57. | 57. | 53.5 | 53.5 | 51 | 46.7 | 52.92 | 6.22 | 159.28 | | 16494.5 |
| 13 | Mar. 28, | 66. | 66. | 64. | 64.4 | | 60. | 65.49 | 5.49 | 149.51 | | 16494.5 |
| 14 | " | 66. | 66. | 65.2 | 65.2 | | 60. | 65.51 | 5.51 | 146.49 | | 16494.5 |

## TABLE V.

*glass cylindrical jar, weighing* 12272 *grains, and receiving such a quantity of water at each experiment as completely to fill the jar when the thermometer and the iron were immersed. Weight of Standard-piece* 6000 *grains. Temperature at immersion* 212°.

| Liquid in therm. in grs. of its equivalent of water. | Total weight of glass in grains including that of the therm. bulb. | Equivalent of glass in grains of water. | Total equivalent of water heated. | Weight of iron X its loss of temperature. | Weight of total equivalent of water X its gain of temperature. | Specific heat of iron. | REMARKS. |
|---|---|---|---|---|---|---|---|
| 91 | 12536 | 1391.5 | 18210. | 923370 | 99881.85 | .10817 | This and the three following experiments were made with the water beginning at temperatures corresponding to those of a series of the same number, made in a thin glass vessel, having precisely the same capacity as the one now used. |
| 91 | 12536 | 1391.5 | 18210. | 901740 | 102340.2 | .11348 | The thermometer here used is the long-bulb spirit instrument C, the specific heat of which is only approximately estimated, the glass at 264 grains, and the alcohol at 242. |
| 91 | 12536 | 1391.5 | 18210. | 925020 | 100155. | .10827 | |
| 91 | 12536 | 1391.5 | 18210. | 940320 | 107985.3 | .11482 | This experiment began and ended below the temperature of the air. The result is consequently too high. |
| 152.7 | 12706 | 1275.2 | 17922.4 | 858360 | 97497.856 | .11358 | This and the three following were made by the aid of thermometer A, having a bulb 7 1-2 inches long, containing at 62° 4670 grains of mercury. |
| 152.7 | 12706 | 1275.2 | 17922.4 | 858380 | 97677.08 | .11382 | These three experiments were intended to coincide with two others made in a series with the thin glass jar; the mean of these three is .11312, that of the other set .11347. |
| 152.7 | 12706 | 1275.2 | 17922.4 | 858680 | 96780.96 | .11272 | |
| 152.7 | 12706 | 1275.2 | 17922.4 | 858600 | 96780.96 | .11272 | |
| 152.7 | 12706 | 1275.2 | 17922.4 | 917460 | 103770.696 | .11310 | The four following coincide nearly with three others made in a series with the thin glass of the same capacity. These several comparative portions of the two series were made with a view of obtaining from them the specific heat of glass. Weight of glass bulb of thermometer A, was carefully ascertained after it had been broken, & found to be 433.85 grains, To avoid fractions, it is here taken at 434. The weight of mercury determined by weighing at the time of filling the instrument. |
| 152.7 | 12706 | 1275.2 | 17922.4 | 921960 | 105383.712 | .11430 | |
| 152.7 | 12706 | 1275.2 | 17922.4 | 928320 | 107175.952 | .11545 too high | |
| 152.7 | 12706 | 1275.2 | 17922.4 | 955680 | 111477.328 | .11560 too high | |
| 152.7 | 12706 | 1275.2 | 17922.4 | 879060 | 98393.976 | .11193 | This and the following may furnish a comparison with the 10th experiment in the table of those made in the thin cylinder of the same capacity. By that comparison the specific heat of glass appeared to be .10036. |
| 152.7 | 12706 | 1275.2 | 17922.4 | 878940 | 98952.424 | .11235 | |
| | | | | | Mean of 14 | =.11288 | |
| | | | | | Mean of Nos. 2, 5, 6 and 9 | =.11349 | These four are the greatest number which *conform* as far as to the third place. |

## TABLE VI.

**TABLE VI.**—*Experiments to determine the specific heat of the iron standard piece used in experiments with the steam pyrometer, employed in this investigation. The heating being performed in a bath of mercury, surrounded with boiling water, and cylindrical jar, weighing 2996 grains, receiving such quantities of water, at each ex-*

| No. of experi. | DATE. | Temp. of air at beginning. | Temp. of air at the end. | Temp. within the tin cylinder at the beginning. | Temperature in the cylinder at the end. | Evapo. point. | Temperature of the water at beginning. | Temperature of the water at the end. | Temperature gained by the water. | Temperature lost by the iron. | Time elap. during the exp. | Weight of water used. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | t′ | t′ | | W. |
| | | ° | ° | ° | ° | ° | ° | ° | ° | ° | | grs. |
| 1 | 1835. Feb. 21, | 57.5 | 58. | | | 50 | 56.09 | 61.95 | 5.86 | 150.35 | 185″ | 16728. |
| 2 | " | 58.5 | 59. | | | 51 | 52.62 | 58.70 | 6.08 | 153.3 | 325 | 16728. |
| 3 | " | 57. | 57.5 | | | 47 | 52.33 | 58.11 | 5.78 | 153.89 | 309 | 16728. |
| 4 | " | 56.5 | 56.5 | | | 47 | 49.35 | 55.66 | 6.31 | 156.34 | 464 | 16728. |
| 5 | April 7, | 57.2 | 67.5 | | | 49 | 63.51 | 69.22 | 5.71 | 142.78 | 154 | 16494.5 |
| 6 | " | 67.1 | 68.2 | | | 49 | 63.50 | 69.26 | 5.76 | 142.74 | 157 | 16494.5 |
| 7 | Aprll 18, | 60. | 60. | 56.75 | 57.25 | 52 | 53.43 | 59.58 | 6.15 | 152.42 | | 16494.5 |
| 8 | " | 60. | 59. | 57.75 | 57.5 | 53 | 52.46 | 58.64 | 6.18 | 153.36 | | 16494.5 |
| 9 | " | 62.5 | 63. | 59.25 | 59.2 | 53 | 51.44 | 57.76 | 6.32 | 154.24 | | 16494.5 |
| 10 | Marh. 28. | 65. | 65. | 63. | 63.6 | | 60. | 65.79 | 5.79 | 146 21 | | 16494.5 |

## TABLE VI.

*periment, as completely to fill the jar when the thermometer and the iron were immersed.*
*Weight of the standard piece, 6000 grains,—temperature at immersion, 212.°*
*Weight of glass container and of thermometer bulb 3250 grains.*

| Equivalent of liquid in the ther. in grains of water. | Equivalent of glass in grains of water. | Total equivalent of water heated. | Weigh of iron × its loss of temperature. | Weight of equivalents of water × its gain of temperature. | Specific heat of iron. | REMARKS. |
|---|---|---|---|---|---|---|
| c. grs. | | grs. | | | | |
| 91. | 360.7 | 17179.7 | 90210 | 100674.8 | .11160 | The first four experiments were performed with a thermometer of spirits of wine, the degrees of which were divided into 100ths, but the performance of instruments of this sort being liable to inaccuracy from the different quantities of liquid taken up at different times in wetting the interior of the tube, the confidence reposed in these results is less than in those of the series with the mercurial therm. (A). The 3d exp. of this table with the 3d of the preceding table gives for specific heat of glass .09651. |
| 91. | 360.7 | 17179.7 | 919800 | 104454.4 | .11356 | |
| 91. | 360.7 | 17179.7 | 923340 | 99300.4 | .10754 | |
| 91. | 360.7 | 17179.7 | 938040 | 108405.8 | .11556 | As the whole process was performed below the temperature of the air, this result must obviously be too high, compared with exp. 4 of preceding table, this gives spec. heat of glass. 12317. |
| 132.7 | 300.6 | 16947.8 | 856680 | 96771.938 | .11296 | This experiment compared with experiments 7 and 8 of the preceding series give for specific heat of glass .110202. |
| 152.7 | 300.6 | 16947.8 | 856440 | 97619.328 | .11398 | This experiment compared with No. 6 of preceding table, gives for specific heat of glass, .11100, but compared with Nos. 7 and 8 it gives .130156. |
| 152.7 | 300.6 | 16947.8 | 914520 | 104228.91 | .11397 | Compared with experiment 9 of the preceding table, this trial gives for an approximate specific heat of glass, .12662. |
| 152.7 | 300.6 | 16947.8 | 920160 | 104737.404 | .11405 | With experiment 10 of preceding table this gives .09715 for specific heat of glass. |
| 152.7 | 300.6 | 16947.8 | 915440 | 107110.095 | .11574 | This experiment was both begun and ended below the temperature of the air. The result must consequently be too high. Compared with experiment 11 preceding table, it gives specific heat of glass .110404. |
| 152.5 | 300.6 | 16947.8 | 877260 | 98127.762 | .11185 | Specific heat of glass derived from a comparison of this experiment with Nos. 13 and 14 of the series in the thick jar is .10036. |
| | | | | | | Mean sp. ht. of glass .111063. |

## TABLE VII.

*Experiments to determine the specific heat of the iron standard piece used in experiments with the steam pyrometer employed in this investigation. The heating being performed in a bath of mercury surrounded with boiling water, and the cooling in two different glass vessels in the two divisions of the series, the heavier weighing* 6923,

| No. of experim. | DATE. | Temp. *outside* the cylinder at the beginning. | Temperature outside at the end. | Temp. *inside* of tin cylinder at the beginning. | Temp. inside at the end. | Temperature of water at the beginning. | Temperature of water at the end. | Gain of temp. by the water. | Loss of temperature by the iron. | Time occupied by the experim. | Weight of water used in grains. | Equiv. of mercury in the thermometer, in grains of water |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | ° | ° | ° | ° | ° | ° | T ° | t ° | ″ | w | e |
| 1 | 1835. Mar. 16. | 65 | 65.5 | | | 60.5 | 68.66 | 8.16 | 143.34 | | 10872 | 152.7 |
| 2 | " | 64.8 | 65. | | | 60.5 | 68.74 | 8.24 | 143.26 | | 10872 | 152.7 |
| 3 | " | 65.7 | 65.8 | | | 60.5 | 68.72 | 8.22 | 143.28 | | 10872 | 152.7 |
| 4 | April 4. | 67. | 68. | 65.2 | 65.7 | 60. | 68.36 | 8.36 | 143.64 | 137″ | 10800 | 152.7 |
| 5 | " | 67. | 66. | 65. | 65.3 | 60.02 | 68.27 | 8.25 | 143.73 | 141 | 10800 | 152.7 |
| 6 | " | 65.75 | 66.25 | 65. | 65.3 | 60.01 | 68.38 | 8.37 | 143.62 | 125 | 10800 | 152.7 |
| | | | | | | | | T′ | t′ | | w | e |
| 7 | Mar. 16. | 65.6 | 65.9 | | | 60.5 | 68.88 | 8.38 | 143.12 | | 10872 | 152.7 |
| 8 | " | 65.5 | 65.8 | | | 60.5 | 69. | 8.50 | 143. | | 10872 | 152.7 |
| 9 | " | 65.3 | 65.4 | | | 60.5 | 69. | 8.50 | 143. | | 10872 | 152.7 |
| 10 | April 4. | 66.25 | 66.25 | 66.1 | 66.3 | 60. | 68.56 | 8.56 | 143.44 | 170 | 10800 | 152.7 |
| 11 | " | 66. | 66.1 | 65.2 | 65.5 | 60. | 68.68 | 8.68 | 143.32 | | 10800 | 152.7 |
| 12 | " | 66.5 | 66.5 | 65.9 | 66.1 | 60. | 68.68 | 8.68 | 143.32 | | 10800 | 152.7 |

## TABLE VII.

*and the lighter* 2465 *grains, receiving equal quantities of water, so as accurately to fill them when the standard piece and the thermometer were immersed. Weight of the standard-piece* 6000 *grains; its temperature at immersion,* 212°.

| Wright of glass in the containing vessel and thermometer bulb. | Equivalent of the containing vessel in water. | Amount of matter heated. | Weight of iron × loss of temperature. | Water × its gain of temperature. | Specific heat of iron. | REMARKS. |
|---|---|---|---|---|---|---|
| g | grs. | grs. | | | | Thicker glass jar. |
| 7356 =433+6923 | 740.16 | 11764.8 | 860040 | 96001.584 | .111624 | The first three of these experiments were made under the tin cone, the next three within the tin cylinder with the cover affixed. The cone could not altogether prevent the circulation of air around the containing vessel. |
| 7356 | 740.16 | 11764.8 | 859560 | 96941.952 | .112780 | The mean result of 2d and 3d experiments may be compared with the identical results of the 8th and 9th, and the formula for that comparison is |
| 7356 | 740.16 | 11764.8 | 859680 | 96706.656 | .112244 | $\frac{(T't-Tt').(w+e)}{Tt'g-T't'g'}=x$ the specific heat of glass of this description. |
| 7356 | 740.16 | 11692.9 | 861780 | 97811.004 | .113498 | The mean result of the 4th and 6th experiments may in |
| 7356 | 740.16 | 11692.9 | 862380 | 96466.425 | .111860 | like manner be compared with the identical results of the 11th and 12th. |
| 7356 | 740.16 | 11692.9 | 861780 | 97811.004 | .113498 | |
| g' | | | | | | Thinner glass jar. |
| 2898 2465+=433 | 290.59 | 11315.3 | 858720 | 94822.214 | .110422 | The 7th, 8th and 9th experiments were made under the tin cone, and the 10th, 11th and 12th within the tin cylinder, the error of one-tenth of a degree is suspected to have occurred in the reading of the 7th experiment. |
| 2898 | 290.59 | 11315.3 | 858000 | 96180.05 | .112098 | The equivalent for the containing vessel in this and the following experiment as derived from a comparison with the 2d and 3d experiments of this series, is 1254. 85, and this gives sp. ht. of iron .111743. |
| 2898 | 290.59 | 11315.3 | 858000 | 96180.05 | .112098 | |
| 2898 | 290.59 | 11315.3 | 860640 | 96242.648 | .111816 | |
| 2898 | 290.59 | 11243.3 | 859920 | 97591.844 | .113489 | The equivalent for the container for this and the following experiment is derived by formula, from a comparison with experiments 4 and 6, by |
| 2898 | 290.59 | 11243.3 | 859920 | 97591.844 | .113489 | which the specific heat of glass appears to be .100620. |
| | | | | | .112409 | Comparing for the specific heat of glass we get from experiments |
| | | | | | | 1 and 8 - .115040 |
| | | | | | | 4 and 11- .100082 |
| | | | | | | 5 and 10- .100004 |
| | | | | | | 6 and 11- .098884 |
| | | | | | | 4 & 6 with 11 and 12- .100620 |
| | | | | | | Mean .103086 |

## TABLE VIII.

*Experiments to determine the specific heat of the Iron Standard-piece used in experiments with the Steam Pyrometer employed in this investigation, the heating being performed in a bath of mercury surrounded with boiling water, the cooling in two*

| Number of the Experiments. | DATE. | Temperature of the air outside of the tin cylinder at beginning. | Temp. outside of the tin cylind. at the end. | Temperature within the cylinder at beginning. | Temperature within at the end of the experiment. | Temperature of the water at the commencement of the experiment. | Temperature of water at the end. | Gain of temperature by the water. | Loss of temperature by the iron. |
|---|---|---|---|---|---|---|---|---|---|
| | | ° | ° | ° | ° | ° | ° | ° | ° |
| 1 | 1835. May 2, | 66. | 66.5 | 65.2 | 62.7 | 49.62 | 52.60 | 2.98 | 159.40 |
| 2 | " | 66.25 | 67. | 64.5 | 63. | 53.70 | 56.54 | 2.84 | 155.46 |
| 3 | " | 66. | 66.25 | 63.5 | 63.2 | 57.06 | 59.82 | 2.76 | 152.18 |
| 4 | " | 66. | 66.5 | 63.8 | 64.1 | 60.22 | 62.84 | 2.62 | 149.16 |
| 5 | " | 66. | 66.25 | 64.8 | 65.15 | 62.95 | 65.42 | 2.47 | 146.58 |
| 6 | " | 66. | 66. | 65.6 | 65.8 | 63.28 | 65.75 | 2.47 | 146.25 |
| 7 | " | 66.5 | 67. | 66.2 | 66.6 | 65.78 | 68.31 | 2.53 | 143.69 |
| 8 | 1835. May 9, | 67. | 67. | 66.9 | 66.9 | 63.88 | 66.34 | 2.46 | 145.66 |
| 9 | " | 66.5 | 67. | 67.1 | 67.1 | 65.78 | 68.26 | 2.48 | 143.74 |
| 10 | May 16, | 64. | 64. | 62.2 | 61.4 | 51.80 | 54.54 | 2.74 | 157.46 |
| 11 | " | 64. | 64. | 61.4 | 61.2 | 55.00 | 57.67 | 2.67 | 154.33 |
| 12 | " | 64.25 | 64.5 | 61.9 | 62.1 | 58.09 | 60.72 | 2.63 | 151.28 |
| 13 | " | 65. | 65. | 62.8 | 63. | 60.88 | 63.31 | 2.43 | 148.69 |
| 14 | " | 65. | 65. | 63.8 | 64.2 | 43.42 | 65.81 | 2.39 | 146.19 |
| 15 | " | 65. | 65. | 64.6 | 65.25 | 65.81 | 68.26 | 2.45 | 143.74 |
| 16 | " | 65. | 65. | 66. | 66.5 | 68.20 | 70.64 | 2.44 | 141.36 |
| 17 | " | 65. | 65. | 67. | 67.2 | 70.46 | 72.72 | 2.26 | 139.28 |
| 18 | " | 65. | 65. | 66.5 | 66. | 63.28 | 65.66 | 2.38 | 146.34 |

## TABLE VIII.

*different copper vessels capable of receiving equal weights of water, but having different thicknesses. Weight of the Standard-piece at the time,* 6000 *grains, and its temperature at immersion* 212°.

| Weight of water employed. | Equivalent of the thermometer in grains of water. | Weight of the copper cylinder. | Equivalent of the containing vessel in grains of water. | Total matter heated. | Specific heat. | REMARKS. |
|---|---|---|---|---|---|---|
| grs. | grs. | grs. | grs. | grs. | | |
| 38659 | 196 | 5178 | 540 | 39395 | .122169 | The first three experiments were begun and ended so far below the temperature of the air, that the water must obviously have received heat from the latter during the whole time. |
| 38659 | 196 | 5178 | 540 | 39395 | .119380 | |
| 38659 | 196 | 5178 | 540 | 39395 | .118504 | |
| 38659 | 196 | 5178 | 540 | 39395 | .114784 | |
| 38659 | 196 | 5178 | 540 | 39395 | .110100 | |
| 38659 | 196 | 5178 | 540 | 39395 | .110366 | Mean of the whole 7 experiments.=11595. |
| 38659 | 196 | 5178 | 540 | 39395 | .115061 | Mean of the last 4.=11257. |
| 38659 | 196 | 19738 | 2056.8 | 40911.8 | .114411 | This and the last six are considered *comparable.* |
| 38659 | 196 | 19738 | 2056.8 | 40911.8 | .118052 | This and the three following give results varying from the rest, partly on account of an excess of heat which kept the steam in the heating apparatus a little too high. |
| 38659 | 196 | 19738 | 2056.8 | 40911.8 | .118676 | |
| 38659 | 196 | 19738 | 2056.8 | 40911.8 | .117933 | |
| 38659 | 196 | 19738 | 2056.8 | 40911.8 | .117407 | |
| 38659 | 196 | 19738 | 2056.8 | 40911.8 | .111405 | |
| 38659 | 196 | 19738 | 2056.8 | 40911.8 | .111318 | |
| 38659 | 196 | 19738 | 2056.8 | 40911.8 | .114565 | |
| 38669 | 196 | 19738 | 2056.8 | 40911.8 | .117661 | |
| 38659 | 196 | 19738 | 2056.8 | 40911.8 | .110609 | |
| 38659 | 196 | 19738 | 2056.8 | 40911.8 | .110869 | This experiment with No. 6, gives by calculation the specific heat of copper .10431. |
| | | | | | Mean of all from 8 to 18=.114990 | |
| | | | | | Mean of 7 comparable=.113261 | |

## TABLE IX.

*Experiments to determine the specific heat of the Iron Standard-piece used in experiments with the Steam Pyrometer. The heating being performed in the bath of mercury surrounded with boiling water, and the*

| No. of Experm't. | DATE. | Temp. of air outside enclosure at beginning of exp. | Temp. of air outside at the close of the experiment. | Temperature of air inside of the enclosing cylinder at the beginning. | Temperature of air inside at the end. | Evaporat'g point. | Temp. of water at the moment the iron was immers'd | Temperature of the water at end of the operation. | Temperature *gained* by the water. | Temperature lost by the iron. | Time elapsed during experiment. | Weight of water in grains Troy. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | †1835. | ° | ° | | | ° | ° | ° | ° | | | |
| 1 | Feb. 7, | 65.5 | 66.5 | | | 50 | 60.8 | 68.1 | 7.3 | 143.9 | 91″ | 13022 |
| 2 | " | 68.25 | 69.5 | | | 50 | 59.9 | 67.3 | 7.4 | 144.7 | 109 | 13022 |
| 3 | Mar. 21, | 66. | 66. | 62.° / 59.5 | 62° / 59.9 | | 51.74 | 59.87 | 8.13 | 152.13 | 376 | 12480 |
| 4 | " | 66. | 66. | 64. / 62.9 | 64. / 63.55 | | 59.4 | 67.11 | 7.71 | 144.89 | | 12480 |
| 5 | " | 67. | 66.5 | 64.5 / 68.45 | 64. / 68.3 | | 57.15 | 64.96 | 7.81 | 147.04 | | 12480 |
| 6 | Mar. 28, | 63.8 | 64. | 63.7 | 63.9 | | 60. | 67.79 | 7.79 | 144.21 | 157 | 12480 |
| 7 | " | 65. | 65. | 64. | 64.5 | | 60. | 67.78 | 7.78 | 144.22 | | 12480 |
| 8 | Apl. 25. | 62.5 | 63. | 60.5 | 60.5 | | 54.51 | 62.52 | 8.02 | 149.48 | | 12240 |
| 9 | " | 62.5 | 62.5 | 62. | 63. | | 62.50 | 69.86 | 7.36 | 142.14 | | 12240 |
| 10 | " | 63. | 63.5 | 63.1 | 63.1 | | 56.3 | 64.06 | 7.76 | 147.94 | | 12240 |
| 11 | " | 63. | 63.5 | 61.8 | 62. | | 56.3 | 63.90 | 7.60 | 148.1 | | 12480 |
| 12 | " | 64. | 64. | 62. | 62.2 | | 56.3 | 63.91 | 7.61 | 148.09 | | 12480 |
| 13 | " | 63.5 | 64. | 61.9 | 62.2 | | 56.3 | 64.10 | 7.80 | 147.9 | | 12480 |
| 14 | " | 63. | 63. | 61.8 | 63.5 | | 56.3 | 64.09 | 7.79 | 147.91 | | 12480 |

## TABLE IX.

*cooling in sheet-iron cylinders of different thicknesses. The standard-piece at the time weighed 6000 grains Troy, and its temperature at the commencement of every experiment was 212°.*

| Weight of the iron containing vessel. | Equivalent of the thermometer in grs. of water. | Sum of the weight of water and thermometer equivalent. | Weight of water × its gain of temperature. | Weight of iron × its loss of temperature. | Weight of container × its gain of temperature. | Specific heat by formula. $\frac{T(w+e)}{it-Tg}=s$. | REMARKS. |
|---|---|---|---|---|---|---|---|
| 1733 | 43.4 | 13065.4 | 95377.42 | 863400 | 12534.1 | .112220 | In this and the two following trials the container was exposed to the direct action of the air, and to radiation from the stove. |
| 1733 | 43.4 | 13065.4 | 96683.9 | 868200 | 12705.8 | .113010 | Near the conclusion of this experiment the thermometer in the water rose rapidly, and soon after fell several tenths, indicating the existence of currents of unequally heated portions of water. |
| 1733 | 196. | 12676. | 103055.8 | 912780 | 13959.21 | .114655 | The container was now placed on a charcoal stand within a tinned iron cylinder, 9 inches in diameter, 14 inches high, through the side of which, near the bottom, passed the stem of a thermometer, another being within it near the top, the scale projecting above. |
| 1733 | 196. | 12676. | 97731.96 | 869340 | 13238.07 | .114159 | |
| 1733 | 196. | 12676. | 98999.56 | 882240 | 13409.77 | .113945 | In this experiment, thermometers in the air were all observed to have fallen during the operation. |
| 1733 | 196. | 12676. | 98746.04 | 865260 | 13375.43 | .115914 | A tin cover perforated at top to receive thermometers, and the iron to be tried, was now placed over the tin cylinder. |
| 1733 | 196. | 12676. | 98609.08 | 865320 | 13358.26 | .115743 | Only one thermometer now placed in the inside of the tin vessel, its bulb at the level of the middle of the water cylinder. |
| 5167 | 196. | 12436. | 99736.72 | 896880 | 41439.34 | .116581 | This experiment ended at the temperature of the air, and may be supposed to give a result too high; a little pressure of steam in the boiler. |
| 5167 | 196. | 12436. | 91529. | 852840 | 38029.12 | .112321 | This experiment having been begun at the temperature of the air may be supposed to give a result too low, the inner air-thermometer rose above the exterior air. |
| 5167 | 196. | 12436. | 96495.6 | 887640 | 40095.92 | .113735 | |
| 5167 | 196. | 12676. | 96339. | 888600 | 39269.2 | .113418 | Half an ounce more water used in this than in the 3 preceding experiments. Care was taken to regulate the height of the furnace so as to keep the temperature precisely at the boiling point, and not to increase the pressure. |
| 5167 | 196. | 12676. | 96456.75 | 888540 | 39320.87 | .113713 | |
| 1733 | 196. | 12676. | 98875.8 | 887400 | 13517.6 | .113142 | These two experiments in the thinner cylinder were intended to furnish a means of comparing the 2 vessels with each other. The result shows the specific heat of sheet iron = .101714. With this specific heat, the mean result of the last four trials is .112945. |
| 1733 | 196. | 12676. | 98738.25 | 887460 | 13500.07 | .112962 | |
| | | | | | Mean of 14= | .113963 | |

After the preliminary series already given, (Tab. IV.) two other sets of experiments were made, one in each of two glass vessels similar to that in which the preceeding trials had taken place,—equal to each other in liquid capacity, but of different thicknesses; the one being more than four times as heavy as the other. Table V. contains the experiments with the thicker, and table VI., those with the thinner of these vessels. The particular object of these trials was to determine, if possible, the effect of the containing vessel on the general result of the experiment; in other words, to decide its specific heat, by observing the difference which would arise from a mere change of thickness in the containing vessel, while all other circumstances of the trial were the same, in both cases. A comparison of several experiments in each table, with corresponding ones in the other, will show that when the water at the commencement was from 60° to 63.5°, the actual difference in the rise of temperature, due to a difference in the weight of the containing vessels of (12272—2996)=9276 grains of glass, was about three tenths of a degree; and from the comparison of nine experiments in the first of these tables, with the same number in the second, it will be seen that we obtain for the specific heat of glass .111063.* A part of the trials in these and the subsequent series were made by means of the spirit thermometer C, the equivalent of which was only approximately found, on account of not having taken the precaution to weigh the bulb and tube separately before filling the instrument. It is, also, like all other spirit thermometers, liable to some uncertainty in its indications owing to the different quantities of the liquid which may at different times be taken up in wetting the tube,—an uncertainty, which is the greater, the more sudden are the changes to which we submit the instrument.

The equivalent value assigned to it by finding the weight and capacity of an equal length of the same tube is 117.4 grains of water, as hereafter mentioned.

The next apparatus used in this part of the investigation consisted of two glass jars, smaller than those above described, both of the same capacity, but differing from each other in weight, being nearly in the proportion of 3 to 1. The experiments in these two vessels were made in two sets of 6 each, three of each set being commenced in the thicker vessels at a temperature of 60°, and three at 60.5°; and the same number at the same two points in the thinner. The results are contained in table VII., where it will be perceived that from five comparisons between the trials in these two jars the influence of the glass is such as to indicate a mean specific heat of .103086, which taken with the above result of the 9 comparisons

* The principle of calculation applied to all these comparisons is embraced in the formula $x=\frac{(T't-Tt').(w+e.)}{Tt'g-T'tg'}$, where $x$ is the specific heat of the container; $T'$ is the gain of temperature by the water when the thinner glass is used; $T$ the gain when the thicker vessel is employed; $t'$, is the loss of temperature by the iron when the thinner, and $t$, that when the thicker is employed; $w$, is the weight of water in both cases, and $e$ the equivalent in grains of water, of the liquid in the thermometer; $g$ is the weight of the thicker jar; $g'$ that of the thinner. Thus comparing the two identical experiments 7 and 8, table V., with experiment 6, table VI. in which the initial temperature of the water, and other circumstances, coincided with the former, we have $T'=5°.76$; $t=143°.1$; $T=5°.4$; $t'=142°.74$; $w=16494.5$ grs.; $e=152.7$ grs.; $g=12.706$ grs., and $g'=34.30$ grs. Hence $T't=824.256$; $Tt'=770.796$; $T't-Tt'=54.46$; $w+e=16.647.2$; $Tt'g=9793733.976$; $T'tg'=2827198.08$; from which $x=.130156$ the specific heat of the glass by this comparison.

between tables V. and VI., gives a mean specific heat of flint glass of .107074.

As we are now only referring to the *apparatus* employed, we shall reserve our remarks on the results presented by these tables, respecting the specific heat of *iron*, until we have described the other methods of verifying their correctness.

The fourth set of apparatus for this purpose, consisted of two cylindrical copper vessels, of the same height as the glass ones already described: but of such diameter as to contain about 38600 grains, or a little over $5\frac{1}{2}$ pounds avoirdupoise of water, and so differing in thickness, that the one weighed nearly 4 times as much as the other. The mode of conducting experiments in these two vessels, and the principle of calculation applicable to them, is entirely similar to that already given for the two pairs of glass jars,—except that the equivalent of the glass in the thermometer, was now separately computed.

The results will be found in table VIII., in which it will be perceived that the number of comparisons furnishing data for determining the specific heat of copper, is but two, and of these only one can be considered entirely unexceptionable.

From this it should seem that the specific heat of copper is .10431, whereas the four determinations of Wilke, Crawford, Dalton and Petit and Dulong give .10750 for the specific heat of that metal.

A fifth mode of determining the specific heat of iron was by employing as water vessels two cylindrical sheet iron jars of the same capacity, but of thicknesses differing from each other in about the proportion of 3 to 1. As in the preceding sets, the specific heat of the container may here be found by comparing together experiments made at the same temperature, in the two vessels; and this ought to give their variation, if any exist, from the specific heat of the standard piece itself. Another method is to assume that the specific heat of the standard piece and of the sheet iron containers is the same.* The use of the two containers in this latter case serves only to verify each others results, since each furnishes a separate and independent calculation.

The results of experiments in the two iron vessels will be found in table IX. A comparison furnished by two experiments in each vessel, gives by calculation on the principle used in the case of the glass containers the specific heat of the Russian sheet iron, of which they are composed = .101714.

### *Results of Experiments on Specific Heats.*

When it is considered that numerous causes interfere with the operations on specific heats, it cannot be expected that one, or a few trials, should be deemed sufficient to settle so difficult and intricate a question. For this reason the committee preferred the method of multiplying and varying the trials, and making a deduction from the mean results, in order to verify the general efficacy of the standard piece, in producing vapour.

1. The first part of the *preliminary series* (table IV.) indicates the effect of radiation from surrounding objects in the apartment to the water

* The formula in this case gives the specific heat of iron $z = \frac{T(w+e)}{it - i'T}$ where $T$ is the temperature gained by the water, $w$ = the weght of water in grains, $e$ = the equivalent of the thermometer in grains of water; $t$ = the temperature lost by the standard piece; $i$ = the weight of the standard piece in grains, and $i'$ = the weight of the sheet iron containg vessel. See *Am. Jour. of Sci.* Vol. 27, p. 277.

vessel. The 13 experiments constituting this part of the table, exhibit a mean result of .123004 as the specific heat of iron.

2. The second part of the same series in which the cylinder B. was employed, indicates a decided effect from that precaution, and gives as a mean result .11294, for the specific heat.

3. Experiments No. 16, 20, 23, 25 and 26, the greatest number of comparable results in this part of the series, (differing only in the fourth place of decimals,) gives a mean of .11346.

4. In table V., where the thicker of the two glass cylinders of the same capacity was used, we have the mean result of the whole 14 experiments .11288.

5. The four experiments No. 2, 5, 6, and 9, which are the greatest number that conform to the third place, give a mean result of .11349.

6. The 10 experiments in table VI., made in the thin cylinder of the same capacity as the foregoing, give the specific heat =.11308.

7. Experiments No. 2, 5, 6 and 7, the greatest number of those which may be regarded as conformable to the third place of decimals, give a mean of .11361.

8. Table VII. contains 3 experiments made in each of the two vessels used in that series, which were performed under a cone of tinned iron to defend the water vessel from radiated heat, but as it was set loosely on the table which supported the container, it did not prevent the motion of air around the latter, and as the experiments made in this manner terminated from three to four degrees above the temperature of the room, there is reason to suppose that the results of those 6 experiments are all below the truth. Taking then the other six of this table, which were made with the same precautions as those in table V. and VI., we have as the mean result in the thicker glass .112952 ; and that in the thinner .113631.

9. The two experiments which conform entirely with each other, for the thicker vessel, give the specific heat .113498, and the two for the thinner .113489.

10. The mean of *all* the results, including both those obtained with the cone, and those with the cylinder of tinned iron, to defend the water vessel, give a mean result of .112350, and the six rejected experiments taken by themselves .111511.

11. In the thinner copper vessel, the trials as recorded in table VIII, exhibit the mean of seven results equal to .115752

12. Rejecting those which began and ended too low, and hence gained heat from the air, as well as from the iron, we have in the thinner vessel .112577 as the mean of four experiments which are considered comparable.

13. In the same table eleven experiments in the thicker vessel indicate a a mean of .114990.

14. With the same jar, seven experiments which are considered *comparable*, give a result equal to .113261.

15. In the thick sheet iron cylinder, weighing 5167 grains, we find by table IX., that the mean of five trials gave a result = .113953.

16. In the same vessel, three experiments which differ only in the 4th place of decimals give a mean specific heat =.113622.

17. In the thinner sheet iron jar weighing 1733 grains, nine trials gave a mean result of .112972.

18. Three experiments in this vessel which differ only in the fourth place of decimals, give a mean of .113365.

The following table embraces a synoptical view of the experiments on specific heat thus far detailed.

**TABLE X.**

| No. of the comparison. | No. of the table referred to | Kind of containing vessel used. | Weight of the vessel in grs. | No. of experiments compared for the general mean. | Mean of specific heats from a comparison of all the trials. | No. of comparable experiments differing in the fourth place of decimals. | Mean specific heat by the comparable results. | No. of rejected experiments | Mean specific heat by the rejected experiments. |
|---|---|---|---|---|---|---|---|---|---|
| 1 | IV. | Thin glass. | 3325. | 13 | .112940 | 5 | .113460 | 13 | .123004 |
| 2 | V. | Thick glass. | 12272 | 14 | .112880 | 4 | .113490 | | |
| 3 | VI. | Thin, containing same as preceding. | 2996. | 10 | .113080 | 4 | .113610 | | |
| 4 | VII. | Thick small glass. | 6923. | 3 | .112952 | 2 | .113498 | 6 | .111511 |
| 5 | VII. | Thin small glass. | 2465. | 3 | .112931 | 2 | .113489 | | |
| 6 | VIII. | Thick copper. | 19738 | 11 | .114990 | 7 | .113261 | | |
| 7 | VIII. | Thin copper. | 5178. | 7 | .115752 | 4 | .112577 | | |
| 8 | IX. | Thick iron. | 5167. | 5 | .113953 | 3 | .113622 | | |
| 9 | IX. | Thin iron. | 1733. | 9 | .113972 | 3 | .113365 | | |
| | | | | 75 | .113716 | 34 | .113374 | 19 | .117257 |

It hence appears that by a mean of 34 out of seventy-five experiments in nine different vessels, with five different liquid capacities, and composed of three different kinds of materials, we obtain a result not sensibly varying from .1134, as the specific heat of the iron standard piece between ordinary temperatures and 212° Fahrenheit.

[TO BE CONTINUED.]

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## *On the Manufacture of India Rubber Web.*

TO THE COMMITTEE ON PUBLICATIONS.

GENTLEMEN:—The general employment of gum elastic web, induces me to send you for publication, a brief notice of the processes for its manufacture, indulging the idea, that it may prove of sufficient interest to amuse, or perhaps instruct some of the many readers of the Journal who are seeking for information.

Circumstances, which need not be related, enabled me to see in detail all that is noted in the following pages, at the manufactory, at St. Denis, near Paris, which, if I am not mistaken, is the only establishment in France, and which has a branch in London, both of which are usually kept impenetrably secret. The fabric was commenced at Vienna, but much improved and extended in the manufactory at St. Denis, in which there are about 1500 of the machines for plaiting the thread around the filaments of Gum, and all the other departments in correspondent proportion.

No pledge was given, nor will any breach of confidence result from the publication of these notes, which were written immediately after the visit to the establishment in 1834. Such as they are, they are at your service, with the best wishes of

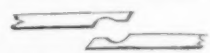
Your obedient Servant,

*Philadelphia, February*, 1837. FRANKLIN PEALE.

1st Operation:—The gum elastic is provided in the usual form of bottles. The first operation is to divide these bottles into two equal parts; they are then placed in piles of six or eight in height and of an indefinite number in extent, upon a plank, and another plank is placed upon them, when the two are drawn together by wooden screws and nuts. They remain in this state a sufficient time to render them flat, or to take out in a great measure the original curvature of the bottles.

2nd Operation.—The first machine contains a circular knife which revolves rapidly, its diameter being about 8 inches. At the side of its edge is an advancing carriage or slide, which receives its movement by means of a screw from the shaft of the knife. Upon this slide is attached the gum, a hole being made in its centre to receive a screw, which serves as a pivot upon which it may turn; it is held down by a nut that is screwed upon it, and the edges are held down by springs placed near to the knife, but not so strong as to prevent its turning under them. A box under the table contains water, in which the knife runs, and a box above it encloses the blade and prevents the water from being thrown into the face of the workman. When the machine is started, the gum advances and is turned round by hand, whilst the knife cuts off the irregular circumference, until a continuous slip comes off, which the workman takes hold of and draws away, the carriage advancing and the knife cutting until the gum is exhausted. The operation resembles the cutting of leather strings out of circular pieces of that material in the manner practised in the olden time by shoemakers.

3d Operation.—These slips pass into a bucket of water, from which they are taken and examined through their whole length by a woman, who removes the defective parts and joins together the ends of the slips, by cuting them off in a sloping direction and making a nick near the extremities, with a pair of scissors, in the manner here indicated. These ends are then placed together and hammered with some force upon an anvil, by which means they are made to adhere with considerable tenacity.



4th Operation.—These slips thus joined pass to another engine, which resembles in almost all respects the slitting mills of iron works, of a size proportionate to the material upon which they operate. The slip, always contained in water, is guided into this cutting mill, which has five or six blades according to the width of the slip, and is kept in its place and prevented from turning by a slight spring. After passing between the cutters it is drawn off by two rollers, between which it passes, and from thence into the hands of the attendant, who passes the slip, thus divided into threads, into water.

5th operation.—The filaments then pass into the hands of females, who examine them through their whole extent, remove the imperfect parts and join the extremities as before.

6th operation.—The next machine is important, having for its object to remove the elasticity of the gum, or in other words, to stretch the filaments to their utmost extent. It consists of a reel of eighteen or twenty inches in diameter, revolving with considerable rapidity. Between the attendant and the reel is a wheel with several grooves of different diameters, revolving with a movement slow compared to that of the reel, and which has a transverse movement from the right to the left side, thus serving as a guide to the filament, and preventing it from overlapping upon the reel. This latter wheel was evidently intended to give an equal tension to the gum as

it was wound upon the reel, but I observed that the filament was simply held by the hand, and the wheel only used as a guide; sufficient practice on the part of the workman, giving to the motion every desirable regularity. The slips are left upon these reels to dry and harden for a period varying from three to six weeks.

7th operation.—They are then wound upon bobbins by the usual means of a wheel and spindle, by a woman, care being taken to retain the tension.

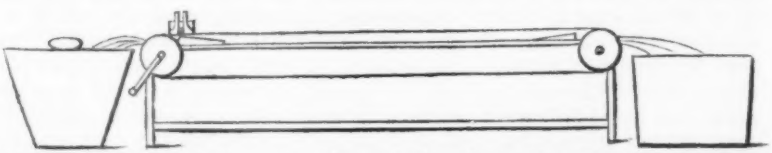
8th operation.—The next operation is the plaiting of silk, cotton, thread or other material, around the filament of gum, previously coloured or white, according to the objects into which it is subsequently to be manufactured. This is performed by an extremely ingenious machine, the construction of which it would be impossible to illustrate without drawings; the machines are manufactured, and for sale in Paris, by Blanchin, No. 98 Rue Faubourg, St. Martin. They have the important quality of stopping if a thread breaks or is exhausted.

9th operation.—The machine last alluded to draws the filament off the bobbins upon which it was previously wound, and after plaiting around it winds it again upon others, which when filled, are conveyed to the looms, and there placed in frames, with a strap and counter weight to give the necessary tension, and in sufficient number to form the warp of the web, which of course varies in width according to the object to which it is destined. The looms were usually simple and moved by hand, but there are also looms capable of weaving six webs or more at the same time, the shuttles of which are furnished with racks by means of which they are carried through the chain.

The plaited filament is combined with silk or other matter, and filled with different materials according to the object of the manufacturer, and in this respect, all the variety of the weaver's art may be exercised.

All the operations thus far noticed have been performed by machinery, driven by a steam engine, with the exception of the looms, which it appears to me are not necessarily excepted. In most of them the gum has been deprived of its elasticity, the last operation consists in restoring this quality. This is effected by taking advantage of that well known though extraordinary character which Gum Elastic possesses, of shrinking by the application of heat.

10th operation.—The machine to effect this is a long table covered with coarse cloth or felting in several thicknesses; at each end is a shaft passing from one side to the other, upon which are pullies,—a strap passes over these pullies, connecting the two ends of the table by a band, which has upon it a crotch. One of the shafts is furnished with a handle to give motion to the whole. These will be best illustrated by a sketch as below: a heavy square smooth iron, heated to a convenient degree, is drawn by means of these straps from end to end; three or four webs are laid upon the table at one time, their extremities on the right are held by weights,



whilst a light block lies upon them at the other extremity, keeping them flat, but not preventing their advancing as they shrink by the application of

the heat of the iron; inclined planes near the ends lift off the weight at the close of the operation. The Iron is of the form here indicated, with wooden handles for convenient management. Baskets at one end and boxes at the other, receive and supply the web.

The web shrinks in length as the heated iron passes over it, to about $\frac{2}{3}$ of the previous length, and has all its original elasticity restored. This operation closes the process, the web being subsequently prepared for sale by being made into rolls and properly packed.

## Physical Science.

### Mr. Redfield *in reply to* Mr. Espy, *on the Whirlwind Character of certain Storms.*

FOR THE JOURNAL OF THE FRANKLIN INSTITUTE.

In the third number of a series of essays by Mr. Espy, published in the Journal of the Franklin Institute this gentleman has called in question the whirlwind movement which I have ascribed to certain violent storms which have visited the western shores of the Atlantic Ocean. The courtesy of his remarks, together with the importance of the fact which he calls in question, induce me, in this instance, to waive the objections which I entertain to any controversial discussion.

The main design of Mr. Espy appears to be the promulgation of a new theory, which is to explain the true causes of "rain, hail, and snow, water-spouts, land-spouts, winds, and barometric fluctuations." But, as some of the results which I have arrived at do not accord with this theory, he has undertaken to examine and refute what he is pleased to call my "theory," with a view, as it would seem, to set aside both the facts and the conclusions which I have formerly advanced, or so far, at least, as they are in collision with his new theory of storms. As the points involved between us are mainly questions of fact, and as Mr. E. has joined issue accordingly, I shall attempt some notice of his "examination," in which it will be most convenient to follow his remarks in their order.

Mr. Espy says, (No. for August, 1836, p. 104-5,) "I come now to a most important part of this investigation, the north-east storms of the Atlantic states. It is well known since the days of Franklin, that these storms commence in the south-west, and travel towards the north-east, with a velocity which varies at different times and places, and that the wind always blows from some eastern point, at the commencement of the storm."

It has been known since the days of Franklin that north-east storms come from the south-west, commencing sooner at Philadelphia than at Boston; but I am not aware that their general or variable velocity was well understood before the publication of my paper, which appeared in the American Journal of Science for April, 1831, and which was drawn up and forwarded in 1830. Dr. Franklin, while in Europe, stated their progress to be one hundred miles an hour; but this is five times greater than their usual rate, which in no case, so far as we know, has much exceeded thirty miles an hour. Indeed, he has qualified this statement as being made from indefinite recollection, and he probably derived his then existing impression from the supposed velocity of wind in violent storms. It was doubtless known, too, that a *north-easterly* storm "always blows from some eastern point;" but I suppose it was not generally known that the S. E. storms pursued the same course as the N. E., and that both the N. E. and S. E., as well as the more south-

erly storms of our coast, are, oftentimes, identically the same; these several winds being found to prevail, at the same point of time, under different quarters of the same storm; and hence the erroneous generalization of the late Dr. Mitchell and others, and, perhaps, of Dr. Franklin himself, which still prevails,* viz. *that all storms begin to leeward:* according to which, our S. E. storms must advance south-eastwardly, &c.—an error which, if I mistake not, I have sufficiently confuted on former occasions. But, to recur again to Mr. Espy.

"Mr. Redfield, of New York, has collected a great many highly interesting facts connected with these storms, of which some of the most important shall now be detailed. When a storm commences within the torrid zone, it travels west of north until it reaches lat. 30°, when it has become nearly north; it then gradually deflects more and more to the east of north, until about lat. 40° it is moving about N. E. That these storms are probably nearly round, varying in diameter, and more slow in their advance along the coast, in proportion to their size, and also slower in low latitudes than in high. That on their north-western side, the wind sets in more northerly, and changes round during the storm by north; and on the south-west side of the storm, the wind sets in at the commencement more easterly and southeasterly, and changes round by the south."—p. 105.

To the last sentence here quoted I feel bound to object, and it should be so corrected as to state the wind as "north-easterly" on the north-western side of the storm, veering, subsequently, by north, towards the west; and that on the south-east side of the storm it sets in with a "southerly wind, which veers gradually to the westward." Such was my language, and such the facts on which my descriptions were founded, and these corrections are important, in regard to the main point at issue. But to return:

"Mr. Redfield thinks that these facts can only be accounted for on the supposition that these storms are exhibited in the form of great whirlwinds."—p. 105.

True; and we can hardly need a more definite description of the elements of a great whirlwind than Mr. Espy has here recognized; especially if it receives the above corrections, to which I think he is bound to assent, notwithstanding the bearing they may have on his favourite theory. Again:

"As a more particular proof of this position, he (Mr. R.) details the facts which occurred in Connecticut, as one of these storms passed there in 1821. He says 'that the mass of atmosphere upon the earth's surface was moving for several hours, apparently, towards the N. W., over Middletown, with a probable velocity of seventy-five or one hundred miles per hour; while in the northern parts of Litchfield county, at a distance say of forty miles, the wind at about the same period was blowing, with nearly equal violence, in the opposite direction, towards Middletown.' Now it will appear, by a little reflection, that all these facts agree with the idea of an upward vortex, more consistently than with a horizontal whirlwind."—p. 105.

I do not know that I appreciate Mr. Espy's idea of an "upward vortex," but he will allow me to say that I am not able to find in my first essay the entire passage which he has marked as a quotation, nor any passage which was intended to express the exact meaning which the above passage conveys. It is true, that in summing, imperfectly, the facts first presented to my notice in this storm, I made use of some part of the above passage preceding

* See, for example, a note on observations made at Dartmouth College, in Silliman's Journal for July, 1835, p. 179, in which the writer says: "It is worthy of remark, as first proved by Dr. Franklin, that storms generally advance *against the wind.*"

the words "equal violence," and then added, "towards the south or south-east." I afterwards inquire "how it could happen that the mass of atmosphere should be found passing over Middletown for some hours with such exceeding swiftness, towards a point apparently within thirty minutes' distance, and yet never reach it; but a portion of the same, or a similar mass of air, be found returning from that point with equal velocity? and how were all of the most violent portions of these atmospheric movements, which occurred at the same point of time, confined within a circuit whose diameter does not appear to have greatly exceeded one hundred miles?"

But the evidence of the facts here spoken of was derived chiefly from my own observation, and this evidence had never indicated, or even suggested, the idea of two opposite winds blowing, at the same time, towards the same point, but a wind blowing in opposite directions, in different parts of a *circuit*, "about the same time." This is an important distinction, though, I acknowledge, it was somewhat obscurely expressed, and is one which Mr. Espy does not appear to have sufficiently noticed. The facts of the case all demonstrated that the south-easterly wind (E. S. E.) which passed over Middletown, became more northerly as it progressed westward, clearly indicating a circuit of action. It should be noted, also, that in the foregoing queries my immediate object was to expose the fallacy of the notion, then universally prevalent, that great winds were always rectilinear in their course and progress. I do not think, however, that my language in that incipient essay was always well chosen, and will concede to Mr. Espy any advantage which it may afford him. But the facts of the case must remain with me, and cannot be yielded, for they seem to prove almost any thing, rather than a centripetal direction of the wind in this storm. Mr. Espy continues as follows:

"Indeed, I do not hesitate to say, that the last fact is inconsistent with a horizontal whirlwind, and proves, with irresistible evidence, the existence of an upward vortex, at least in this storm. For two winds cannot blow towards each other for several hours, as here described, without either rising upwards when they meet, or blowing outwards at the sides. But we have proof positive that they did not blow outwards at the sides, for at New York, S. W. of the point between Middletown and Litchfield, to which the winds from those places were blowing, the wind changed round by the N. to the N. W. or W., about the time these winds began to blow violently, and we have strong reason to believe that it did not blow outwards to the N. E.; for at the commencement of the storm, through its whole course, the wind always blew from some eastern point."—p. 105.

Having already, as apart from the language referred to, denied the existence of the supposed facts on which these strictures and reasonings of Mr. Espy are founded, it can hardly be necessary to examine them further. It is sufficient to say that I know of no facts respecting this storm which indicate that the wind blew either outwards or inwards, (in Mr. E.'s sense) as regards its geographical centre; and my information is derived not only from the newspapers of that day, (which are defective, and to some small extent erroneous in their statements,) but from extensive personal inquiries made at the time, among seafaring men, who were exposed to the gale on Long Island Sound, and at other places.

I directed my inquiries in regard to the real phenomena of this storm, to its direction at a given point of time, say at nine o'clock on the evening of Sept. 3d; and it then appeared that on the south-eastern borders of Connecticut the gale was blowing from the southward—that in the northern part

of that state, about Connecticut river, the gale was S. E., or more eastward —that in the north-western part of Connecticut, it was at that time N. E., or more northward—that at New York, and on the lower parts of the Hudson, it was then north-westerly—and that on the outside of Long Island it was south-westerly. Now, these being the facts, we have here a circuit of wind, which bears about the same relation to a whirlwind that a *ring* bears to a *circle;* and unless Mr. Espy can show that we are mistaken in our facts, his objections must be abandoned as untenable. For the whole matter, as already suggested, resolves itself into a question of fact, and is one that may be, or could have been, easily determined. But let us attend again to Mr. Espy, whose remarks I have thus far cited at length, for the purpose of giving full force to his objections:

"There is one conclusion which Mr. Redfield draws, which I do not find to be justified by the facts detailed in this storm. 'That along the central portion of the track, the storm was violent from the south-eastern quarter, *changing suddenly to an opposite direction.*' Now I find that of fifteen points on the south-east side of the storm, at which the wind set in S. of E. only two—Bridgeport, Conn., and one at sea, forty miles north of Cape Henry—are given as having the wind to change round, even as far as the west. These two I *suspected* as being contrary to my theory; and upon examination of the newspapers of the day, I find that they report the wind at both these places to have changed round only to the south-west, just as far as it *should* change to satisfy my theory."—p. 105.

There are two sources of fallacy to which Mr. Espy was here exposed in his examination. First, the confounding of "points on the south-east side of the storm" with those on the central portion of the track, where the wind set in nearly at S. E.; and secondly, in not considering that newspaper accounts of gales of wind, in our ports or at sea, in most cases specify only the general direction of the wind at the onset of the gale, and omit to notice with sufficient particularity, if at all, the subsequent changes or veering of the wind to the westward, down to the time that the storm of wind wholly disappears. In regard to the point here at issue, every experienced seaman can inform Mr. E. that when these gales are experienced from S. E. on our coast, the change in almost every case is to the opposite or north-western quarter, and this point is settled with more certainty than almost any other position in popular meteorology. Now, if we take an approximate centre of the route on which this gale exhibited its greatest violence, it will be found to coincide nearly with that line on which the gale set in from south-eastward, and on which, after exhibiting its greatest violence, the wind suddenly ceased to be felt, and, after a calm of some fifteen or thirty minutes, as suddenly renewed its violence in a direction nearly from N. W., in disregard of Mr. E.'s theory; and while these marked phenomena were in progress along this line, on either side, at the distance of some ten or fifteen miles, there was no intermission of the wind, but a changing or *veering*, more or less gradual, to a western quarter.

We find from my running specification, which Mr. Espy had before him, that near the coast of Virginia, Maryland, and New Jersey, immediately in the track of vessels bound along shore, the wind set in from south-eastward, and blew with great violence; and that one of these accounts, as well as two others from the shores adjacent, specify the change to have been to the N. W. or W. N. W. On the continuation of this range across Long Island, the Sound, and through the states of Connecticut and Massachusetts, as I learned from strict and numerous inquiries, and in part witnessed, the first

direction, and subsequent change of the wind were, successively, the same; and if these successive directions of the wind happen to be nearly at *right angles* with the course which Mr. Espy's theory requires for the same localities in this storm, it is chargeable to no fault or mistake of mine, but must be ascribed to the powers which govern the wind.

In relation to the south-eastern side or margin of the track of this storm, where it was felt with diminished effect, we of course find more difficulty in obtaining definite reports in regard to the wind. One captain, however, who was seventy miles from the land, off New Jersey, reports the wind at only one point from *south*, probably at the onset of the gale; and another still farther off, upon the edge of the gulf stream, reports the gale in general terms "from the westward," (perhaps from S. W.) probably as opposed to the *eastward*, from some point of which it is more common to encounter the gale. Other vessels, which could not have been at a much greater distance from the coast, felt nothing of this storm. But the subsequent arrival of the gale upon the southern shores of New England has left us no room for doubt upon this point; for at the eastern extremity of Long Island Sound, and the neighbouring ports, the gale commenced from the southward. Now, as this was on the south-eastern side of the gale, and as the progress of the storm was about N. N. E., it follows that this south wind was also entirely out of place as regards Mr. E.'s theory, which I suppose would require the wind in this locality to have been nearly at right angles to the course of the storm, say at E. S. E.

On the north-western, or inland, side of this storm, the evidence is, if possible, still more tangible and conclusive; for at Philadelphia, Trenton, and other places, which fell successively under this margin of the gale, the wind was *north-easterly*, a course directly contrary to the progress of the storm; a fact which I had distinctly specified, but which Mr. Espy has suppressed in his examination, and which appears equally irreconcilable with his hypothesis, which supposes the wind on all sides to blow towards the centre of the storm. Now, as the whole active or violent portion of the gale appears to have passed between the highlands of the Hudson on one hand, and Montauk Point, or Block Island, on the other, it follows that, at these places, under the western verge of the gale, a north-westerly wind, at this time, would have been more appropriate to his theory. The subsequent veering of the wind to N. W. at these places, does not obviate the discrepancy, for this result necessarily attends the departure of a whirlwind storm, which is turning always towards the left, around its progressive axis of motion.

In my published communications on this subject, I have thought it necessary to avoid the detail of a multitude of concurrent facts which have obtained my notice since I have engaged in this inquiry; and I have presented the storms of Sept. 3d, 1821, and Aug. 17th, 1830, as types of their class, giving only a synopsis of some of the most distinct accounts from the public journals, and leaving out of view a great mass of evidence, both of a positive and negative character, but all tending to confirm the conclusions which I have presented. My notices of the first of these storms we have just reviewed, and those of the storm of 1830 are so decisive in their bearing, that a detailed analysis seems unnecessary. The track of these storms, and of several others of the same class, will be found on the annexed chart, which has recently been published, and is now presented to the readers of the Journal of the Frankin Institute.

In the remarks of Mr. Espy which follow those last quoted, he attempts to connect his theory with the great rains of May, 1833, and June, 1835.

This may serve to show us the importance of more distinct definitions, or of such a classification of storms as shall serve to distinguish a hurricane, or gale of wind, from a mere rain storm, or period of rain. "A tempest accompanied by rain," I believe, is always attended by a fall of the barometer, at least if it be of the whirlwind character; but the rains or storms here referred to were, on the contrary, accompanied by an unusual elevation of the mercurial column, and are of that description of weather which I have formerly characterized as being "more frequent in April, May, and June, than in other months," and which has been unusually frequent during the present year;*—the East wind flowing as a regular current.

Mr. Espy here says: "I have known many instances of long continued and violent rains in the south, during the prevalence of a strong and long continued north wind, and of long continued and violent rains in the north, during the prevalence of a strong and long continued south wind. An instance of the latter occurred on the 11th, 12th, 13th, 14th, and 15th of May, 1833. In my journal it is stated that a strong south wind prevailed during this whole period, night and day." And after reciting accounts of the heavy rains in Pennsylvania, New York, Canada, and the Connecticut valley, he remarks: "These facts afford conclusive evidence that in this case, at least, the wind at Philadelphia blew hard for five days, exactly towards one of the greatest rains which our country has ever witnessed."—p. 106-7.

I find, on recurring to my own journal and files, that the great rains of that period extended from Texas to the Gulf of St. Lawrence, and from the Atlantic Ocean to the great lakes and the far west; from which it follows, that almost any wind at Philadelphia would be found blowing "towards" the point where it rained. The winds at New York, during this period, though chiefly south-easterly, were varied in their direction over more than half of the horizon. Their strength, or velocity, is marked in my journal as *faint*, *light*, *moderate*, and *fresh*—of which last, but one half day is thus distinguished, leaving five terms unused, by which I am accustomed to express higher degrees of velocity in the wind. The movement of the clouds, during this time, was chiefly from the S. W. quarter, as is most usual. The mean of the barometer from the 11th to the 16th, when the rain ceased, from observations taken every four hours, was 30.08 inches. The mean during *all* the rains of April preceding was 29.80, and during those of the remainder of June succeeding, 29.92.

Mr. Espy says: "Again, from the 3d of June, 1835, to the 12th of the same month, the wind was constantly from the north, with one exception from the north-east." He then states that a dreadful storm of rain set in at Charleston on the 3d, and another very violent one on the 8th, increasing on the 9th, &c., and remarks: "These facts seem utterly at variance with a horizontal whirlwind, and entirely consistent with an upward vortex, if they do not prove one."—p. 107.

The facts in this last case, I think, are sufficiently "at variance" with either conclusion, as referring to the whole of the above period. At New York, where I should think the weather ought not to differ greatly from Philadelphia, we had the wind, June 2d, a moderate breeze from W. S. W., weather fair—3d, wind moderate from S. S. E. to E., and cloudy—4th and 5th, we were under the south-eastern part of a moderate storm of the whirlwind kind, which probably contributed largely to the rains of the south, in

*1836.

its passage over that region, and which must have passed chiefly inland of our position at New York, the wind veering from the south to the south-west quarter, with varying strength, with alternate rain, thunder and lightning, and fair weather. During its passage, the barometer settled to 28.86 inches. On the 6th and 7th, a *current* wind, light and moderate, flowing from N. N. E. and round to S. E.; weather fair, and barometer very high. From 8th to 12th inclusive, wind somewhat variable, but chiefly a moderate breeze from south-westward, and weather fair, excepting rain on the 12th, with the wind moderate from south.

During nearly the whole of this period, the upper current of the region of clouds was from the north-westward, a course which, even there, is certainly not towards Charleston or North Carolina. It is to the chilling effect of this current (then, perhaps, in a state unusually cool) upon the undermoving stratum of air coming from the low latitudes of the Atlantic, that I chiefly ascribe the heavy rains of this period, which fell in the southern states. The mean of the barometer for this period, excepting forty-eight hours during the passage of the whirlwind storm, was 30.19 inches; and it rose under the easterly wind of the 8th, to 30.58 inches; while the mean during all the rains for the remainder of the month was but 29.87, and during the rains of the month of May, excepting one storm of similar character on the 21st, the mean was 29.88 inches. Whether the foregoing state of facts, as regards the rain, be most favourable to the theory of Hutton, or of Mr. Espy, I leave for others to determine.

Another set of facts relating to the direction of wind in the vicinity of our storms, deserves the consideration of Mr. Espy. Many of these storms move along our coast, exhibiting rain with a north-easterly wind at Philadelphia and New York, and extending some distance at sea. Now, during the passage of many, if not most, of these storms, the wind at Albany is from the southward, and also over a large extent of interior country. So well known is this fact among those who navigate the Hudson, that they seldom hesitate to assert it, while these winds are prevailing; and I have often had occasion to know that their position is in most cases correct.

Having compared Mr. Espy's theory with some of the facts of the case, as relates to the foregoing storms, we may now, in a theoretical point of view, propose the following inquiries for his consideration. If a storm, perhaps of some hundred miles in diameter, blows from all sides "directly towards its centre," and with a velocity of seventy or eighty miles an hour, by what physical force is it thus impelled, encountering, as it does, more or less resistance on every foot of the surface over which it passes? What effect has the momentum of these opposing movements from all sides, at the storm's centre? The supposed centripetal wind, in passing over less than a third of the radial distance to the storm's centre, would, by its concentration, appear to be doubled in quantity on each foot of surface, and in passing two-thirds of its course towards the centre, must continue to accumulate to nine times its original quantity: by what miracle is such a violent and extensive confluence of atmosphere prevented from raising the mercurial column to an unknown height? By what process is the mighty volume thus concentrated again disposed of, and sent back to its original distance, while less than the average pressure is found at the surface beneath? What has become of the laws of gravitation, or what principle of "levity" has been discovered which can explain such remarkable phenomena? How is the equable horizontal movement so often visible above the storm, and recognized by Mr. Espy, to be reconciled with such an extensive and violent

confluence, and upward motion? And if this be the true theory of rain storms, how can it be applicable to hurricanes, which are so essentially different in their character? During the rain-storms we have considered, the barometer was above its mean elevation, but in a storm of the whirlwind kind it is greatly depressed; and how can such opposite effects be produced by the same causes, and explained by the same theory? What can be more unlike than the hurricanes and the *rains* of the West Indies? and what is the general resemblance between these hurricanes and the rains of Cayenne and Guiana, where hurricanes are unknown? Can a theory of rarefaction by the latent heat of condensed vapour be adequate to the solution of all these difficulties? Should not the amount and strength of the wind be, in all cases, in proportion to the quantity of vapour condensed? And if the supposed rarefaction be admitted to exist, are the physical difficulties of the case, as above mentioned, at all lessened thereby? It is acknowledged by Mr. E. that "a mere expansion and swelling up of the air would not diminish its gravitation;" and if it were otherwise, can any degree of *upward* force account for the known phenomena of a great gale? How shall we obtain upward action separate from the same amount of downward reaction?" Mr. E. will pardon me if I remind him that "if gentlemen will frame such theories, they ought not to be surprised if a little plain arithmetic should dissipate their visions."

But rain is a concomitant of storms, and Mr. Espy desires to have a theory which shall account both for the gale and the rain, whether both be associated in the same storm or not! and he is kindly desirous of seeing me enlisted with the supporters of such a theory. The suggestion is received with equal kindness and good feeling; but I must discredit all the evidence of nature, as presented to my own mind, before such a course can be rendered possible; and, as a friend to the science, I have no wish to see the zeal and talents of so able a meteorologist as Mr. Espy expended in this particular direction. There is good reason to apprehend that mistaken theories and hypotheses have hitherto constituted both the ground-work and the bane of this interesting science. In the present state of our knowledge, facts are far better than theories, and it seems needful that we should place ourselves for a while under the exclusive guidance of the former.

In the department of geographical meteorology, we doubtless need a more extensive collection and grouping of observations, from all parts of our extensive territory, than has hitherto been obtained. It appears probable, too, that our meteorology will prove more systematic and regular in its character than that of Europe, notwithstanding the great variableness of our climate. We want the means of determining the extent to which our great inland storms partake of the character, either of whirlwind or current, or both, and in what various degrees of combination. We want the means of tracing these storms, and other marked changes of weather, towards their geographical sources, or points of origin, such as can only be afforded by a combination of barometrical and other observations, collected from the broadest extent of our inhabited domains. We want collected an array of facts, occurring in such select portions of time as shall comprise our most remarkable phenomena, and promulgated in tabular, or other condensed, forms; such, in short, as meteorologists have been long expecting from the able committee at Philadelphia, of which Mr. Espy is chairman, and which it may be expected they will yet furnish; so that all the facts thus collected may be equally available to their distant correspondents as to themselves, for the purposes of generalization.

But, to return to our immediate topic, let us suppose, if possible, that Mr. E. has found an upward influence, or tendency, existing at the centre of a storm, sufficient for his purpose,—I then wish him to try the following experiment: Take a large circular vessel, filled with water, which contains in suspension saw-dust, or some other material which will show the direction assumed by the particles of the fluid when set in motion; then make a circular orifice in the centre of its bottom, and we shall have a downward force of gravitation equal, at least, to the supposed upward force of rarefaction, and, which is still better, the forces from all parts of the circumference will press *directly towards the centre.* An examination of the direction which the currents assume in the vessel, under the influence of this downward discharge, will illustrate, in a measure, the true character of an atmospheric vortex which discharges itself continuously upward,—a movement quite different in its character from that which Mr. Espy supposes to take place.

I am not here called upon to explain the somewhat varying character of the movements and phenomena which usually occur when the warm air of the lowest stratum is transferred to a greater elevation. In my own view, both the facts and theory of such transfer but ill accord with the received system of meteorology, and are not to be understood or explained by the current chimney-theory, or the stereotype course of chimney-reasoning which is everywhere adopted, and which Mr. Espy seems to carry to the extreme of ultraism. Nor is it, as may have been perceived, my intention to deny any upward movement, or tendency, at the centre of a whirlwind storm; for of such a movement, apart from theory, I have long since obtained good evidence,—a movement, however, which has but little resemblance to that for which Mr. Espy contends.

I am not able to perceive that the "upward vortex" of Mr. Espy, which we may suppose to be somewhat fairly represented in his figure, can be considered as a vortex, in any proper sense of the term; for he nowhere recognises the gyratory, or vorticular motion around a determinate axis, which is essential to a vortex. Nor does it appear that his supposed upward movement at the centre of a storm bears any strong analogy to a vortex, for, if an atmospheric vortex discharge itself upward, as probably happens in all cases when the lower stratum is much warmer than the next higher, still, if the axis of motion be vertical, or nearly so, the main direction of the vorticular motion must be nearly horizontal, but tending spirally upward at a rate which is proportioned to the activity of the whirling movement, and the smallness of the circuit.

The only known vortex whose axis surrounds a common centre, and which, if that axis should chance to be in a horizontal plane, may gyrate in an upward direction on its inward limit, is the *ring vortex*, which is sometimes formed artificially, by the discharge of cannon, or other fire-arms. But of this vortex we have no example in meteorology, and if it were possible to produce its action on an enlarged scale, and with the ring in a horizontal position, it would fail to answer Mr. E.'s requirements. The action of all ærial or fluid vortices, in order to be long continued, I apprehend, must be nearly, though not absolutely, circular, moving around *an axis, or centre, of less density, or pressure, than the exterior of the gyratory circuit.* It is in this last condition, if I mistake no*t*, that the gyratory *power* of all whirlwinds, and whirlwind storms, is chiefly to be sought.

Again: If the axis of an atmospheric vortex be *horizontal*, or nearly so,

its lateral, or radial, dimensions cannot be great, because of the rarity of the air in the higher regions, as well as of the small natural limit in that direction. Its lateral extent must, therefore, be limited to a few thousand feet, at the most, and its contact with the surface, in the direction which is transverse to its axis, must be equally circumscribed, as is seen in the case of a common thunder storm. Nor can such a vortex, if its action is to be maintained, discharge itself freely, if at all, in the direction of rotation; nor will its centrifugal action sensibly lessen the atmospheric pressure over any considerable extent of country.

In my investigations of the hurricane storms, instead of attempting to make a theory to account for rain, I have mainly endeavoured to ascertain and generalize the facts as exhibited in nature, well knowing that, if this is correctly done, any supposed theoretical difficulties on this or other points can only be imaginary. And I have been much surprised that gentlemen so well versed in natural science as Mr. Espy, and Prof. Mitchell, of North Carolina, should conceive of such a mathematical rotation in a whirlwind, of great or small size, as would result in no change in the relative positions and condition of its particles. They appear to have overlooked the obvious fact already alluded to, that the rotation of a continued whirlwind involves not only changes in the position and condition of its constituent particles, but a constant accession of the exterior atmosphere to the body of the whirlwind, together with a discharge equally constant, spirally, at one extremity of its axis of rotation. These facts are easily substantiated, and they are of course comprised in my own theoretical views of whirlwinds and whirlwind storms.

That I have not attempted, therefore, to show "that the whirlwind" motion in these storms "is the cause of the rain," is partly because I deemed it inexpedient to engage in the discussion of general theories, and partly because I supposed that, to meteorologists, this connexion must be sufficiently evident; and, lastly, because it is obvious, if not undeniable, that whirlwinds have produced some of the most violent rains that have ever visited the earth's surface. That I do not, on the other hand, "pretend to show that the rain is the cause of the whirlwind," is because I deem such a conclusion, if not absurd, to be at least indefensible. There are, however, many points connected with the theory of meteorology that need a rigid discussion in view of facts, both of common notoriety, and of others which are daily being brought into notice; but this field is perhaps too inviting for one to enter, who is not professionally engaged in these or kindred pursuits.

Mr. Espy considers me as ascribing the whirlwind action of hurricane storms to the impingement of the margin of these storms upon the West India islands, and upon our own coast. He here has reference to a hypothetical explanation of the origin of the rotative motion, attempted in my first paper, on which no great stress was then laid, and which, like many other hypotheses, is entitled to little consideration; and I may here state that I do not pretend to sustain *all* the incidental remarks that may be found in that essay. The origin and determinate course of the rotative motion in these storms can be explained, however, upon established principles, and, I trust, in a satisfactory manner. But it is my design not to enlarge, at this period, the field of discussion. It is sufficient to have pointed out the leading facts relating to these storms, and I leave it for others to scrutinize them, or to follow out their obvious and important indications.

In various portions of Mr. Espy's essays, and especially in his fourth number, published in October, there are assumptions and reasonings regard-

ing his upward vortex, and also relating to its supposed connexion with the fall of the barometer, with which I would not willingly interfere, and which, I am apprehensive, he will one day view as being sufficiently extravagant and untenable.

In regard to the depression of the barometer, which I have ascribed to the rotary action of whirlwind storms, Mr. Espy has himself shown that the centrifugal action in a storm which gyrates horizontally, must tend to withdraw or rarify the air at the centre, by causing a transfer and accumulation towards the exterior of the storm, thus causing a higher state of the barometer around the exterior border, than at the centre of the gale. This connexion and result, which I endeavoured to point out and establish in my first essay, is in strict accordance with the facts of the case, as exhibited in all storms of this character, so far as my observations and information extend; and I have but little objection to the formula which Mr. E. offers, subject to such corrections for countervailing tendencies as the case requires. Indeed, the depression of the barometer in the interior of a storm is often known to be greater than his theoretic result of $1\frac{4}{10}$ inches. The case does not, however, involve, as he supposes, a greater pressure or accumulation of atmosphere around the exterior of the storm, than is actually found to exist. A practical illustration of this case may be found in any strong eddy, or whirlpool, which we may find in action, surrounded by a considerable extent of quiescent water. The depression of the centre occasioned by the centrifugal action will be obvious, but it will be hard to detect any considerable rising of the exterior, above the surrounding surface. The same observation will also show that there is seldom any motion or current outwards, from the circumference of the whirl or vortex, but the tendency of motion, as observed, is rather inwards, by gradual or spiral approximation towards the centre.

Having, in the course of these remarks, reviewed the "examination" of Mr. Espy, and shown the variance between his new theory and the facts of the case, as relates to the storms before mentioned, and having also alluded to some of the more obvious objections to which his theory of storms appears liable, it is unnecessary to enlarge the range of this discussion, although it may seem desirable to point out many of his apparent assumptions or misconceptions of phenomena, to which I have already made a partial allusion.

I am pleased to find that Mr. Espy coincides with me in support of so many of the facts and generalizations which I have ventured to advance on former occasions; and in order to show how narrow and defined is the ground of difference between us, I will here notice some of those coincidences, including those also which are comprised in the circulars and reports of the Joint Committee on Meteorology, of which Mr. Espy is chairman. The principal generalizations in which we thus coincide are the following:

1st. *In the tropical latitudes of the North Atlantic, the storms move towards the north-west.*

2d. *Storms from the tropical latitudes of the North Atlantic change their course to the northward and eastward, on reaching the latitude of* 30° *north.*

These results are recognised and acknowledged by Mr. Espy; and he states, also, as a fact, that the upper [or main?] current of air in these latitudes moves in the same direction; which, I presume, is inferred from the above, as he does not refer to any other evidence.

3d. *The upper, or main, current of air in the United States is "from some westerly point."*

The course of the storms from some westerly point having been estab-

lished, and the inference above alluded to being allowed here, this conclusion will of course follow. It is confirmed, also, by my observations of the course of the clouds for the last five years,—a synopsis of which observations, for the years 1833 and 1834, was published in the report of the Regents of the New York University, and in the American Journal of Science, in 1835.*

4th. "*The barometric fluctuations of great magnitude (in the United States) travel north-eastwardly.*"

As these remarkable fluctuations generally attend a violent gale, their joint progress towards the north-east is of course inseparable. I therefore suggested, in my earliest essay, a theoretical solution of this hitherto inexplicable phenomena,—a solution which appears both obvious and natural, viz: *the centrifugal influence which necessarily attends the action of a whirlwind storm.* The importance of the above generalization, however, is not lessened by being now put forward by the Philadelphia committee in an insulated form.

5th. "*Storms, in the temperate zones, travel from some westerly point.*"

This hypothetic generalization, advanced by the committee, which I had also expressed in other terms, is supported by my published investigations of the course of storms, and I have obtained much evidence which goes to establish this point. It is hoped that the committee will also be able to furnish us with new evidence, from other regions, confirming this generalization.

6th. "*Storms which so travel* (from a westerly point) *are usually preceded by an easterly, and followed by a westerly, wind.*"

The committee's generalization here referred to, though approximately correct, is less accurate than the more specific statements prepared by me for the American Coast Pilot, in 1833, and published also in the American Journal of Science for January, 1834.

7th. "*In the torrid zone, storms on the north side of the line travel to the north-west, and on the south side of the line, to the south-west.*"

This result is also comprised in my former generalizations, and it would be interesting to know if the committee, either before or since their hypothetical adoption of the same, have obtained new facts in its confirmation.

8th. *Is not "the velocity of the upper [or main] current of air" nearly that with which the storm travels? and "is it not this current which gives direction to the storms in this latitude?"*

The committee will find my generalizations on these points expressed in my former papers, from which I adduce an instance in the following passage published in January, 1834. "Whirlwinds, [whirlwind storms,] of whatever form and extent, and however violent, move forward only with the velocity of the more regular wind *by which they are impelled.*"

There is no danger, however, of obtaining too much evidence in favour of any or all of these conclusions, and the committee will be rendering good service to the cause of science in bringing together the facts of the case in their proper relations, and in spreading the same before the public. It is also proper to state here, in order to prevent misconception, that in adopting the foregoing generalizations, as indicated by the marks of quotation, the committee have, in every case, expressed the same in the hypothetical or interrogatory form.

9th. *A "vortex"* [whirlwind] *is a common cause of rain, and sometimes produces rains of the most violent character.*"

Mr. Espy accords with me by recognizing the fact in relation to his own

* Silliman's Journal, vol. xxviii. p. 154.

"vortex," and the result is not materially altered by his supposed misapprehension of its real nature; and some of the interesting examples which he has adduced are among the many upon my own files, upon which I rely to establish this point. His views of the *modus operandi* of the "vortex," and of its vertical extent and concomitant movements, are, unfortunately, quite at variance with my own. Had he possessed, from the first, a full knowledge of my facts, and of my theoretical views in regard to them, it is possible that our views might have more nearly harmonized.

10th. *A violent vortex, or whirlwind, in hot weather, frequently produces hail of extraordinary size, and such a vortex always constitutes the nucleus of a summer hail-storm.*

11th. *A water-spout, sand-spout, land-spout, or tornado, consists of a vortex,* [*whirlwind*] *and some of its attendant phenomena.*

12th. *It is by the agency of a vortex, or whirlwind, of extraordinary violence and activity,* (*such as is known to attend volcanic eruptions,*) *that the extraordinary ascent of volcanic ashes and other light articles is produced, and which afterwards fall in showers at great distances from their point of origin.*

13th. *The action of a vortex, or whirlwind, frequently produces violent electric action, accompanied with noisy and continued explosions, or concussions, electric flashes, a fiery appearance, if at night; including also thunder and lightning, with rain and hail.*

These are, substantially, but reiterations of my former generalizations, and to each of these last may be applied the remarks which are made under the ninth specification.*

The main question which is directly at issue between Mr. E. and myself, on the present occasion, is that of the *centripetal*, or the *rotative*, course of the wind, in the violent storms which sometimes visit our coast: And I submit the following as a summary outline of the facts upon which I rely, in maintaining the whirlwind character of these storms.

I. In that portion of the *front* of a storm which approximates to the centre of its geographical route, or track, when advancing north-eastwardly, the wind is found to be *south-easterly*.

II. On the *left flank*, or border, of the storm, as it thus advances along our coast, the wind, during the earlier part of the storm, is found to be *north-easterly*,—a direction *contrary* to the course of the storm.

III. On the *rear*, or hinder portion, of the storm, on the centre of its track, the wind is found to blow *north-westerly*.

IV. On the *right flank*, or border, of the storm, while advancing as above, the wind is found to be *south-westerly*,—a direction which *coincides* with the course of the storm.

V. At intermediate points of the circuit, these several directions of the wind, *as regards the same point of time*, are found to approximate to each other.

VI. It is therefore A FACT, that these storms blow in the form, or manner, of a great whirlwind. This is as truly and properly a fact, as the revolution of the earth in its orbit, or around its axis, or as any other event which involves as great a succession of time, space, and motion.

It can be of little importance to Mr. Espy, or myself, to carry a point in this discussion, for truth in physical science will remain truth, and, in this

* It should be observed that the generalizations above specified were distinctly put forth by the writer of this article, in various modes of expression, as early as January, 1834. It also appears that they came under the review of the Chairman of the Joint Committee, more than a year previous to the publication of their first Report, in July, 1835; in which they are mainly adopted as original generalization.

nge of exact observation, is sure to be discovered; and I now take leave of it, with sentiments of high respect for his industry and talents, and with the best wishes for his success, while labouring to enlarge the boundaries of science.

Upon the chart which is annexed to this communication, as illustrative of the general subject, I have indicated the routes of various hurricanes and storms, as derived from numerous accounts in my possession, by which their progress has been identified for several days in succession. I add, also, the following running descriptions, which will serve to illustrate the same more fully.

The route designated as No. I, is that of the hurricane which visited the islands of Trinidad, Tobago, and Grenada, on the 23d of June, 1831. Pursuing its course through the Caribbean sea, it was subsequently encountered by H. M. schooner Minx, and other vessels, and its swell was thrown with great force upon the south-eastern shores of Jamaica, on the 25th, while passing that island, where the wind, at this time, was light from the northward. After sweeping through the Caribbean sea, this hurricane entered upon the coast of Yucatan, on the night of June 27th, having moved over the entire route from Trinidad to the western shore of the Bay of Honduras in a little more than one hundred hours, a distance of about seventeen hundred nautical miles, which is equal to nearly seventeen miles an hour. I have no account of this storm after it crossed the peninsula of Yucatan. Its course or track to Honduras was N. 74° west.

Track No. II, is that of the memorable hurricane which desolated Barbados on the night of August 10th, 1831, and which passed Porto Rico on the 12th, Aux Cayes and St. Jago de Cuba on the 13th, Matanzas on the 14th, was encountered off the Tortugas on the 15th, in the gulf of Mexico on the 16th, and was at Mobile, Pensacola, and New Orleans, on the 17th; a distance of 2000 nautical miles in about 150 hours, equal to something more than 13½ miles an hour.* Its course, until it crossed the tropic of Cancer, was N. 64° west, or W. N. W. nearly.

Track No. III. is that of the destructive hurricane which swept over the Windward Islands on the 17th of August, 1827; visited St. Martin's and St. Thomas' on the 18th; passed the north-east coast of Hayti on the 19th; Turks' Island on the 20th; the Bahamas on the 21st and 22d; was encountered off the coast of Florida and South Carolina on the 23d and 24th; off Cape Hatteras on the 25th; off the Delaware on the 26th; off Nantucket on the 27th; and off Sable Island, and the Porpoise Bank, on the 28th. Its ascertained course and progress is nearly 3000 miles in about eleven days, or at the average rate of about eleven miles an hour. The direction of its route before crossing the tropic, may be set down at N. 61° west, and in lat. 40°, while moving eastward, at N. 38° E.

Track No. IV. is that of the extensive hurricane of September, 1804. It swept over the Windward Islands on the 3d of that month; the Virgin Islands and Porto Rico on the 4th; Turks' Island on the 5th; the Bahamas and gulf of Florida on the 6th; the coast of Georgia and the Carolinas on the 7th; the great bays of Chesapeake and Delaware, and the contiguous portions of Virginia, Maryland, and New Jersey, on the 8th; and the states of Massachusetts, New Hampshire, and Maine, on the 9th; being, on the highlands of New Hampshire, a violent snow storm. The destructive action of this storm was widely extended on both sides of the track indicated upon the chart, and the same fact pertains, in a greater or less degree, to the other storms herein mentioned. It appears to have passed from Martinico, and the other

* All the distances are expressed in nautical miles.

Windward Islands, to Boston, in Massachusetts, by the usual curvilinear route, in about six days; a distance of more than 2,200 miles, at an average progress of about 15¼ miles per hour.

Track No. V. represents the route of the hurricane which ravaged the islands of Antigua, Nevis, and St. Kitt's, on the afternoon and night of Aug. 12th, 1835; St. Thomas, St. Croix, and Porto Rico on the 13th; Hayti and Turks' Island on the 14th; the vicinity of Matanzas and Havana on the 15th; was encountered off the Tortugas, in the gulf of Mexico, on the 16th; in lat. 27° 21, lon. 94°, and other points, on the 17th and 18th; and also at Metamora, on the coast of Mexico, (lat. 26°,04) on the 18th, where it was most violent during the succeeding night. This storm is remarkable, as moving more directly, and farther to the west, than is usual for storms which pass near the West India Islands, it having reached the shores of Mexico before commencing its sweep to the northward. Its course, so far as known, is N. 73° west. Its progress, more than 2,200 miles in six days, which is nearly equal to 15½ nautical miles an hour.

Route No. VI. is that of the memorable gale of August, 1830, which, passing close by the Windward Islands, visited St. Thomas' on the 12th; was near Turks' Island on the 13th; at the Bahamas on the 14th; on the gulf and coast of Florida on the 15th; along the coast of Georgia and the Carolinas on the 16th; off Virginia, Maryland, New Jersey, and New York, on the 17th; off George's Bank and Cape Sable on the 18th; and over the Porpoise and Newfoundland Banks on the 19th of the same month; having occupied about seven days in its ascertained course from near the Windward Islands, a distance of more than 3000 miles, the rate of its progress being equal to 17 miles an hour.* If we suppose the actual velocity of the wind, in its rotary movement, to be five times greater than this rate of progress, it will be equal, in this period, to a rectilinear extent of 15,000 miles. The same remark applies, in substance, to all the storms which are passing under our review.

Route No. VII. is that of an extensive gale, or hurricane, which swept over the Western Atlantic in 1830, and which was encountered to the northward of the West India Islands on the 29th of September. It passed on a more eastern route than any which we have occasion to describe, to the vicinity of the grand bank of Newfoundland, where it was found on the 2d of October, having caused great damage and destruction on its widely extended track, to the many vessels which fell in its way. The ascertained route may be estimated at 1800 miles, and the average progress of the storm at 25 miles an hour.

Route No. VIII. is that of a much smaller, but extremely violent hurricane, which was encountered off Turks' Island on the 1st of September, 1821; to the northward of the Bahamas, and near the lat. of 30°, on the 2d; on the coast of the Carolinas early in the morning of the 3d; and from thence, in the course of that day, along the sea-coast to New York and Long Island; and which, on the night following, continued its course across the states of Connecticut, Massachusetts, New Hampshire, and Maine. I am not in possession of accounts by which its farther progress can be successfully traced. The diameter of this storm appears not to have greatly exceeded 100 miles; its ascertained route and progress is about 1800 miles, in sixty hours; equal to thirty miles an hour.

* For a more extended notice of this storm, see Silliman's American Journal of Science, vol. xx. p. 34—38.

WESTERN ATLANTIC,
WITH THE COURSES
of Various
HURRICANES.
By
W C REDFIELD.
1855.
CANADA
NEWFOUNDLAND
St LAWRENCE GULF
Quebec
NOVA SCOTIA
Halifax
Sable I.
Boston
New York
Philadelphia
Baltimore
WASHINGTON
UNITED STATES
Charleston
Bermuda
New Orleans
Mobile
Galveston
Matamoras
Tampico
CUBA
HAITI
JAMAICA
Antigua
Guadaloupe
Martinique
Barbadoes
Grenada
Trinidad
Margarita
Tortuga
PACIFIC OCEAN
COLUMBIA
Sept 29th 1850 VII
Aug 12th 1850 VI
Aug 12th 1853 I
Sept 3rd 1804 II
Aug 12th 1827 III
Aug 10th 1851 II
27th June 1851 I
Aug 22nd 1850 IX
Sept 1st 1821 VIII
Oct 19th
XI 1855 Nov 10th
100°
95°
90°
85°
80°
75°
70°
65°
60°
55°
50°
45°
40°
35°
30°
25°
20°
15°
10°

The last mentioned route may also be considered to be nearly the same as that of a similar, but less violent storm, which swept along the same portion of the coast of the United States, on the 28th of April, 1835.

No. IX. represents the route of a violent and extensive hurricane, which was encountered to the northward of Turks' Island on the 22d of August, 1830; northward of the Bahamas on the 23d; and off the coast of the United States on the 24th, 25th, and 26th of the same month. Much damage was done on the ocean by this storm, but it scarcely reached the American shores. Its duration off this coast was about forty hours, and its progress appears to have been more tardy than that of some other storms.

No. X. represents the track of a violent hurricane and snow storm, which swept along the American coast, from the lat. of 30° N., on the 5th and 6th of December, 1830.

The last mentioned track also corresponds to that of another storm, of like character, which swept along the sea-coast on the 13th, 14th, and 15th of January, 1831. These winter storms exhibit the same phases of wind and general characteristics, as those which appear in the summer and autumn.

Track No. XI. represents a portion of the general route of the violent inland storm which swept over the lakes Erie and Ontario, on the 11th of November, 1835. This storm was very extensive, spreading from the sea-coast of Virginia into the Canadas, to a limit at present unknown. The anterior portion of this gale was but moderately felt, and its access was noted chiefly by the direction of the wind, and the great fall of the barometer, the violence of the storm being chiefly exhibited by the posterior and colder portion of the gale, as is common with extensive overland storms. The regular progression of this storm in an easterly direction is clearly established by facts collected by the writer, from the borders of Lake Michigan to the gulf of St. Lawrence, and the sea-coasts of New England and Nova Scotia.

I have thus given a summary description of the route of twelve storms, or hurricanes, which have visited the American coasts and seas, at various periods, and at different seasons of the year. The lines on the chart, which represent the routes, are but approximations to the centre of the track or course of the several storms; and the gales are to be considered as extending their rotative circuit from fifty to three hundred miles, or more, on each side of the delineations, the superficial extent of the storm being estimated both by actual information, and by its duration at any point near the central portion of its route, as compared with its average rate of progress. The figure which appears upon the chart, on tracks No. I., V., and VII., will serve, in some degree, to illustrate the course of the wind in the various portions of the superficies covered by the storm, at one point of time, and, also, to explain the changes in the direction of the wind, which occur successively at various points, during the regular progress of the gale.

## Civil Engineering.

### *On the Velocity of a River's Current, at different depths.*

FOR THE JOURNAL OF THE FRANKLIN INSTITUTE.

It has often been questioned whether the current of a river be equable from its surface to its bottom. Some suppose that the velocity of the current is greatest at the surface; others, that it is greatest near the bottom.

The most general, and, I think, the most correct opinion, is, that the velocity of the current of a river, or stream, is greatest at the surface, and diminishes at every point from the surface towards the bottom, and that at the bottom there is no, or scarcely any, current.

While I resided at Harrisburg, in the summer of 1811, a gentleman and myself made the following experiment:

A machine or instrument like that represented in the annexed figure was made by a cabinet maker. A B and C D are two sticks, an inch square, and about five feet in length, connected at the distance of about seven inches from each other by the cross pieces *e f* and *g h*. E and F are two thin boards, exactly five inches square, (we called them fans,) connected by a stick G H, an inch square; the whole length from the top of E to the bottom of F being exactly three feet.

*i k* is a pin passing through A B, and C D, and G H, being fast to G H at *d*, but turning freely in the holes through which it passes in A B and C D.

Holes were also made in the three sticks, A B, C D, and G H, at *l a m*, at *n b o*. and at *p c q*, the holes being exactly an inch apart, for the purpose of moving the pin *i k* (when required) from the centre of G H, one inch, or two inches, or three inches, above the centre.

We went in a skiff to the middle of the river between Harrisburg and Maclay's island, and anchored the skiff at a place where the river was about five feet in depth, and the velocity of the current, according to our estimation, about four miles per hour. The instrument was set in the river perpendicularly, B D being on the ground at the bottom, the side of the instrument being to the current, so that the current should strike the fans E and F. The fan E was about two inches beneath the surface of the river, and the fan F three feet lower in the water. The frame A C, B D, was held steadily in a perpendicular position, and the stick G H, connecting the fans E and F, was suffered to turn on the pin *i k*, as it should be forced by the current of the river. The upper end of the stick G H, and the fan E, immediately inclined down the stream, and the lower end of the stick and the fan F inclined up the river; so that the stick G H formed an angle of perhaps thirty degrees with the frame A B C D, which was held perpendicularly.

The pin *i k* was then inserted through the holes at *p c q*, and afterwards at *n b o*. The fan E was still pressed by the current down the stream, though to a less and less distance as the pin was moved from *d* to *c*, and then from *c* to *b*. At length the pin was inserted at *l a m*, being three inches above *d*, the centre of the stick G H. Upon setting the frame carefully in the current, the stick remained nearly perpendicular, but still the fan E was pressed a little down the stream, and forward of the upright frame A B C D. The pin *i k* was always fastened to the stick G H, when it passed through the holes at *d c b*, or *a*, and permitted to turn freely in the holes through which it passed in A B, and C D.

As the stick G H was just twenty-six inches in length, and as the fans were each five inches square, from the centre of E to the centre of F was thirty-one inches; and when the pin was placed at *l a m*, it was three inches above the centre, giving to the fan E a lever of $12\frac{1}{2}$ inches, and to the fan F a lever of $18\frac{1}{2}$ inches, measuring from the pivot point *a* to the centre of each fan. The velocity of the current near the surface at E being, to its

velocity at F, (thirty-one inches lower down in the water) in the proportion of 18½ to 12½.

It would be interesting to repeat the experiment under different circumstances; for example, in currents of two, and in currents of six, or more miles per hour; in rivers of three, and in rivers of ten, or more feet in depth, and with the lower fan (as F) as near as could be to the bottom.

The reason of the current of rivers or streams being greatest at the surface, and diminishing gradually to the bottom, seems to be manifest. It is on the principle of bodies falling or sliding down inclined planes. The application of the principle is more obscure and difficult in the case of the river, on account of the falling or sliding body being a liquid, instead of a solid body.

It is on the same principle that the velocity of the current of a river increases, in proportion as it is swelled and raised higher and higher by rains and floods. E.

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*On the Velocity of Floating Bodies along the Current of a River.*

When I lived in Harrisburg, I often heard raftmen and boatmen say that rafts, loaded boats, and arks, floated faster than the current of the Susquehanna. They said that when a rise occurred in the river, in consequence of a heavy rain above any particular point, say Sunbury or Wilkesbarre, if a boat or raft started with the flood, it would soon go beyond the flood, and get into shallow water, and that, for this reason, it was their practice never to start till the rise, or flood, had preceded them about twenty-four hours.

They also said that a heavy boat, or raft, floated faster than a light one, and that, by fastening two or more rafts together, their speed was increased.

The facts seemed probable, independent of the direct testimony of the boatmen, and to be accounted for on the principle of falling bodies, and bodies sliding down inclined planes, acquiring velocity in their progress, the acquisition of velocity being in proportion to the inclination of the plane, and the weight of the descending body.

To ascertain the fact that a loaded boat floated faster than the current, the following experiment was made in the summer of 1811, by several scientific gentlemen, with myself.

A common water wheel was made, about sixteen inches in diameter, and fastened *to the end* of a stick, or shaft, about two feet in length. We entered a skiff, and went to a rapid part of the river, where the current, for the distance below us of one hundred yards and upwards, was even, and of the rapidity, as we estimated it, of five miles per hour. The skiff was anchored; I sat in the middle of it, hanging the water wheel over the side of the skiff, so that the wheel dipped an inch, or more, in the water. The shaft rested on the side of the skiff, and I held it loosely in my hands, allowing it to turn round freely, as the current gave motion to the wheel.

While the skiff remained at anchor, the force of the current made the wheel turn pretty quickly upwards, or against the stream. The rope that held the skiff to the stone that served for an anchor was cut, and the skiff was allowed to float down the river. The skiff gradually but rapidly increased in the velocity of its motion, and the motion of the water wheel turning upwards, or against the current, proportionably diminished in velocity. After the skiff had floated not more (as well as I can remember at

this time) than four or five rods, the motion of the wheel on its axis, or shaft, ceased altogether, and it began to turn on its axis down the stream, slowly at first, but quickly increasing. And after the skiff had floated not more (I think) than fourteen or fifteen rods from the place where it had been anchored, the water wheel turned downwards, or with the current, as often as once round in the distance of a rod, or less.

It is evident that while the wheel turned up the stream, the current of the river went faster than the skiff, or ran past it; and when the wheel turned down the stream, the motion of the skiff was more rapid than that of the current. We expected this result in a certain degree, but all of us were surprised that the floating skiff should so soon acquire a velocity greater than that of the current of the river.

It would be interesting to repeat this experiment under change of circumstances. For instance:

1. In a slower, and in a more rapid, current.
2. In a boat heavily, and one lightly, loaded.
3. In a flat bottomed, and in a sharp keeled, boat.
4. On rafts of different sizes.

Also, to ascertain whether any difference would arise from having the load lie in the bottom of the boat, such as a quantity of pig metal, or having the load consist of men standing up in the boat.

Times and distances should, of course, be accurately noted. E.

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### *Estimate of the Water discharged by a River.*

If the currents of rivers diminish from the surface towards the bottom, and be very slow at the bottom, the quantity of water discharged by rivers into the ocean is much less than has been usually imagined. Dr. Halley, in his theory of the origin of springs, probably estimates much too largely the quantity of water poured into the ocean by all the rivers of the world.

When the dam at Fairmount, near Philadelphia, was erected across the Schuylkill, it was stated, in some of the newspapers, that some gentlemen wished to ascertain the quantity of water that flowed in the river in a given time. For this purpose, the newspapers said that the breadth and depth of the river at Fairmount were measured, and that to obtain the velocity of the motion of the water in the river, four or five gentlemen entered a boat, and floated a certain distance on the river, noting the time required to pass a given distance, after the boat had acquired its *natural velocity and motion*, as it was called.

If the newspaper account was correct, it would seem that two great errors entered into the calculation.

*First.* The current diminished in velocity from the surface to the bottom, the current in the bottom of rivers being very slight, unless in places where the descent in the bottom, or bed, is considerable, as at rapids or ripples.

*Second.* The boat loaded with four or five men floated much faster than the fastest part of the current of the river, faster than the current at the surface. E.

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## Franklin Institute.

### *Annual Meeting.*

The Annual Meeting of the Institute was held at their Hall, on Thursday evening, Jan. 19th, 1837,

James Ronaldson, President, presiding;
Isaac B. Garrigues, Recording Secretary, P. T.

The minutes of the last Quarterly Meeting were read and approved.

Donations of books were received from the Lords Commissioners of the Admiralty, through William Vaughan, Esq., of London; A. L. Elwyn, M. D.; Prof. A. D. Bache; Hon. James Harper; and Messrs. Mordecai D. Lewis, Daniel Groves, Abraham Miller, and Edward H. Gill.

Thomas U. Walter, Esq., presented an engraving of the Girard College.

Messrs. John F. Frazier and John C. Trautwine presented specimens of minerals.

Mr. Joseph Brano presented plaster casts of specimens of the Trilobites.

Mr. Henry D. Campbell presented a model of a bridge, constructed upon Town's plan.

The Actuary laid on the table the periodicals received during the past quarter, in exchange for the Journal of the Institute.

The annual report of the Board of Managers was read, and, on motion, was accepted, and referred, for publication, to the Committee on Publications.

The Treasurer presented his report of the funds for the last quarter, and also a statement for the year ending December 31, 1836—which were accepted.

The Chairman of the Committee on Publications presented the report on the operations of the Journal of the Institute, for the year ending December 31, 1836, which was accepted.

The Chairman of the Committee on the Explosions of Steam Boilers presented the general report of that committee, which was accepted.

Mr. John Horten, from the Committee of Tellers appointed to receive the votes of the members for officers and managers of the Institute for the ensuing year, presented their report of the result of the election, when the President declared the following gentlemen duly elected:

James Ronaldson, President.
Isaiah Lukens, Thomas Fletcher, } Vice Presidents.
Isaac B. Garrigues, Recording Secretary.
Isaac Hays, M. D., Corresponding Secretary.
Frederick Fraley, Treasurer.

*Managers.*

| | |
|---|---|
| Samuel V. Merrick, | Alexander M'Clurg, |
| Abraham Miller, | Joseph S. Walter, Jr. |
| William H. Keating, | Samuel Hufty, |
| Rufus Tyler, | John C. Cresson, |
| John Struthers, | James M. Linnard, |
| Matthias W. Baldwin, | Andrew M. Eastwick, |
| Alex. Dallas Bache, | Isaac P. Morris, |
| Benjamin Reeves, | Earl Shinn, |
| J. Henry Bulkley, | *Charles B. Trego, |
| Alexander Ferguson, | *Henry Troth, |
| John Agnew, | *John S. Warner, |
| John Wiegand, | *Willliam Hart Carr. |

(Extract from the minutes.)

James Ronaldson, *President.*

Isaac B. Garrigues, *Rec. Sec. P. T.*

* New members.

## *Thirteenth Annual Report of the Board of Managers of the Franklin Institute.*

In pursuance of the duty imposed by the constitution, the Board of Managers lay before the society a succinct history of the transactions of the past year, and an exposition of the condition and prospects of the Institute.

From the foundation of the association, a leading object with its managers has been to provide sound instruction, by means of popular lectures upon scientific subjects. Of these, Chemistry and Natural Philosophy have claimed primary consideration, as being most intimately connected with mechanic arts, and the ordinary pursuits of life. For some years past, chemical knowledge has been imparted to the class by Dr. J. K. Mitchell, in a manner that has won for him the affection and respect of all his hearers; and the science of Natural Philosophy has been illustrated by Prof. W R. Johnson, with the assiduity and minuteness of research which form prominent features of his character. To these gentlemen the thanks of the Board are due, and are thus publicly tendered, for their exertions in the cause of education. These lectures occupy two evenings in each week; and a third has heretofore been appropriated to the delivery of volunteer lectures, upon such subjects as are calculated to promote the great objects of the Institute. During the present season, the Committee on Instruction have been able to secure for the class regular lectures, three times a week, by engaging the services of Mr. J. C. Booth for a course upon arts and manufactures, from which the members are now deriving a fund of useful and entertaining knowledge. The drawing school, under the superintendence of Messrs. William Mason and John M'Clure, is fulfiling the most sanguine expectations to which its success in former years had given rise; the number of pupils is seventy-five; and several applicants have been excluded by the limited extent of our accommodations.

Second only to the lectures and schools as the means of disseminating knowledge, is the Journal of the Institute,—a work which bears ample evidence of the talents and industry devoted to its pages. Although the subscription list has been considerably augmented in the past year, the Board feel constrained to state that it does not yet experience a patronage by any means commensurate with its merits. The volume just completed contains a large amount of original matter, tending directly to the improvement of some important branch of industry, or highly interesting to the scientific and general reader.

It may perhaps be deemed worthy of notice, that since the destruction of the Patent Office, the only authentic records of American patents, other than those in possession of the patentees themselves, are to be found in the volumes of this Journal.

The Library is steadily increasing in extent, and bids fair, in the course of a few years, to comprise most of the standard works connected with the arts and sciences.

The whole number of volumes now amounts to 1700; of which have been added during the past year, by purchase 84, in exchange for the Journal 64, and 51 were received as donations.

Immediately connected with the library is the reading room, and the Board have observed with much gratification that a daily increasing number of members avail themselves of the intellectual repast here provided for the student, the mechanic, and the man of business.

The number of newspapers now received is 39, of journals devoted to

science and mechanics 44, of which 8 are from Paris, 17 from London, and 19 published in the United States.

In the Cabinets of Models and Minerals, there has not been any change during the past year requiring special notice. Some donations have been added to both collections, and they have been reduced to systematic arrangement by the committees to whom they are respectively entrusted.

The Monthly Conversation Meetings are regularly maintained, and continue to be attended with considerable interest; but it is believed that their beneficial influence might be increased, if members would more generally bear them in mind, whenever an opportunity is presented of bringing forward specimens of ingenuity or skill. Although these meetings are placed under the superintendence of a committee of the Board, it was not intended, nor could it be expected, that they should be sustained by the efforts of that committee alone; and it is confidently hoped that members will feel it incumbent upon them not to suffer this excellent feature of the Institute to be lost for want of proper exertion.

The labours of the Committee on Science and the Arts have been prosecuted with the same assiduity and success as marked their progress during the two previous years.

The Committee has been deprived of the services of one of its most valued members, by the mission to Europe of its late chairman, A. D. Bache, Esq. The chair thus vacated has been filled by the election of Dr. R. M. Patterson, a gentleman whose accomplishments and love of science are sufficiently well known, both at home and abroad, to secure for the body over which he presides, a continuance of that confidence which the public have heretofore reposed in its decisions.

The number of subjects brought under the notice of the committee during the year, is 43; lying over from last year, 7. Of these, 41 have been disposed of by report, or otherwise, and 9 remain under consideration. Sixteen members have recorded their names on the committee this year, and one member, Mr. Benjamin Say, has deceased, leaving the present number 81.

In conformity with a regulation adopted some years back, the Institute has held no exhibition of domestic manufactures during the past season, but opportunity has been afforded to manufacturers for a display of the products of their skill at the conversation meetings.

In accordance with the same regulation, an exhibition should be held in the ensuing autumn; and the subject is recommended to the next Board, as claiming their early and serious deliberation.

The Committee on the Explosions of Steam Boilers having at length concluded that branch of their labours which relates to the strength of materials, the results will shortly be laid before the public on the pages of the Journal. The report comprises a large number of tables, involving calculations of a complicated nature, and forms, in conjunction with the parts already published, a fund of practical information, founded on elaborate research, such as is rarely to be found in any of the periodicals of the day.

In the past year, 171 gentlemen have been elected members of the Institute, 18 have become life members, 78 have resigned, and 10 deceased; the whole number of members is now 2004. The names of gentlemen who have become life members are as follows: Messrs. Charles Alexander, Alex. Dallas Bache, Wm. A. Blanchard, Caleb Clothier, Eli Dillin, John F. Frazier, A. B. Hutton, John Horton, L. Johnson, Warner Justice, Joseph S. Lovering, Wm. Mason, Joseph S. Newbold, Abraham R. Perkins, Geo. Parkinson, Joseph Price, Jr., Thomas Ryan, and John M. Scott.

The Treasurer's report is herewith submitted.

MATTHIAS W. BALDWIN, *Chairman.*

WILLIAM HAMILTON, *Actuary.*

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*Minutes of the Board of Managers.*

At a meeting of the Board of Managers, held at the Hall of the Institute, January 25th, 1837,

Mr. JOHN STRUTHERS was elected Chairman of the Board; and

Messrs. FREDERICK FRALEY, and JOHN C. CRESSON, Curators for the ensuing year.

And at a meeting of the Board, held February 15th, the Chairman nominated the Standing Committees, agreeably to the by-laws. On motion, Mr. JOHN STRUTHERS was added to the Committee on the Cabinet of Models, and Prof. HENRY D. ROGERS, and Messrs. JAMES C. BOOTH and JACOB PEARCE to the Committee on the Cabinet of Minerals; when the committees were appointed as follows:—

*On the Library.*

Henry Troth,
Isaac Hays, M. D.
Thomas Fletcher,
Isaac P. Morris,
Earl Shinn,
J. Henry Bulkley,
Alexander M'Clurg.

*On the Cabinet of Models.*

John Agnew,
John Struthers,
Benjamin Reeves,
Joseph S. Walter, Jr.
Isaac P. Morris,
Andrew M. Eastwick,
John S. Warner,
William Hart Carr.

*On the Cabinet of Minerals.*

Isaiah Lukens,
Samuel Hufty,
Abraham Miller,
William H. Keating,
Charles B. Trego,
Henry D. Rogers,
James C. Booth,
Jacob Pearce.

*On Publications.*

Isaac Hays, M. D.
Samuel V. Merrick,
Matthias W. Baldwin,
Rufus Tyler,
John C. Cresson.

*On Premiums and Exhibitions.*

John C. Cresson,
William H. Keating,
Alexander Ferguson,
Thomas Fletcher,
Frederick Fraley,
Isaac B. Garrigues,
Alexander M'Clurg,
John S. Warner.

*On Instruction.*

Frederick Fraley,
John Wiegand,
James M. Linnard,
Joseph S. Walter, Jr.
Isaac P. Morris,
Earl Shinn,
Charles B. Trego.

*On Monthly Meetings.*

Rufus Tyler, Henry Troth,
Matthias W. Baldwin, John S. Warner,
Andrew M. Eastwick, William Hart Carr.
John C. Cresson,

*Managers of Sinking Fund.*

Samuel V. Merrick, Frederick Fraley,
Alexander Ferguson.

*Auditors.*

Isaac B. Garrigues, Rufus Tyler.

(Extract from the minutes.)

JOHN STRUTHERS, *Chairman.*

WILLIAM HAMILTON, *Actuary.*

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**Progress of Practical and Theoretical Mechanics and Chemistry.**

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*Improvement in Bleaching Fats.*

A patent was granted to William Septimus Losh, for his invention of an improved method of bleaching certain animal fats, and certain animal, vegetable, and fish oils.—[Sealed 17th July, 1834.]

The Patentee says, his invention consists in making the oils and fats or fatty matter to which the process is applicable, miscible with water, in such manner as effectually to admit of the application of a solution of chloride of lime to bleach the same, and in the use of the said solution, in manner hereinafter explained, for that purpose.

I take a quantity of the oily or fatty matter to be bleached, and add to it one-twentieth of its weight of caustic potash, or soda, or one-twelfth of its weight of the carbonate or chloride of potash or soda dissolved in a quantity of boiling water equal in bulk to the oily or fatty matter to be bleached, taking care to stir the mixture until it is perfectly uniform and free from knots. I then take chloride of lime of commerce equal to one-fourth of the weight of the said oily or fatty matter to be bleached, and having dissolved it in cold water in the proportion of six hundred gallons of water to one hundred-weight of chloride of lime, I draw off the clear solution from the residuum, and allow the clear and cold solution of chloride of lime to trickle slowly into the mixture before mentioned while it is still sufficiently warm to be in a liquid state, at the same time very carefully stirring the whole mass.

When this is done, the bleaching action speedily commences, and proceeds gradually during the addition of the cold solution of chloride of lime, and for some time afterwards, until the colour is sufficiently discharged.

The bleached oily or fatty matter I then put into some kind of boiler that will resist the action of sulphuric acid (I have found an ordinary iron boiler lined with lead answer the purpose perfectly well,) and boil it in diluted sulphuric acid in the proportion of one part sulphuric acid, of 120° strength, to twenty parts of water, until it is freed from any of the lime or alkaline substance which may have combined with it during the bleaching process, and floats quite clear upon the top of the acid liquor, after which

I draw it off into clean water to free it from any adhering acid or other impurities, and it is then ready for use.

Now, whereas the quantities and proportions of the substances hereinbefore given may be considerably varied, without materially affecting the process; but in the proportions before stated I have found the bleaching is very speedy and complete, and is applicable to such oils as linseed, palm, whale, and seal, and to such fats as impure tallow, and what is commonly called grease or kitchen-stuff.

I claim as my invention the bleaching of such oils and fats or fatty matter as aforesaid, by combining the said oils and fats with water holding in solution an alkali and alkaline substance, then gradually mixing with the fluid mass so obtained a cold solution of chloride of lime in manner hereinbefore described, the subsequent processes of boiling in acid and washing in warm water being merely to free the bleached substances from the extraneous matter which has been imported into them by my method of bleaching.

Lon. Jour. Arts and Sciences.

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*Manufacture of Gas.*

A patent was granted to Jean Baptiste Mollerat, manufacturing chemist, for his invention of certain improvements in the manufacture of gas for illumination.—[Sealed 25th September, 1834.]

This invention consists in *utilising* the vapour of certain volatile liquids which are very rich in carbon, to render luminous certain gases which are not so, though they are combustible. I employ for this purpose several volatile liquids, hereinafter named: 1st. the *very* volatile liquid obtained from the distillation of the tar produced in the manufacture of gas or coke.

The tar, distilled at a gentle heat, furnishes an oil composed of the sesquicarburet and the bicarburet of hydrogen, containing generally in 100 parts, 91.2 of carbon, and 8.8 of hydrogen. It is known that the sesquicarburet of hydrogen contains 90.02 of carbon, and 9.98 of hydrogen; and the bicarburet 92.35 of carbon, and 7.65 of hydrogen: each of these two bodies boils at 186° of Fahrenheit, and possesses very great elasticity; their density is the same, being 0.86; water being 1. at the ordinary temperature.

The liquid I employ will support a degree of cold, equal to the zero of Fahrenheit, without solidifying, which proves that it contains a sesquicarburet which remains liquid at that low temperature, while the bicarburet becomes solid at the freezing point of Fahrenheit.

Coal tar, produced in the manner above stated, yields 10 to 12 per cent. of the volatile oil above mentioned, proper for the use of my patent; but the first product of this distillation is the only one proper to be employed for that object, without being rectified; what comes over afterwards, is mixed with an oil that boils only at 212°, and contains, besides, napthaline, which only boils at 380° of Fahrenheit. If this second product were employed, a second distillation would be necessary to get rid of the oil and napthaline, in an apparatus, on the principle of that of Woolf. If coal were distilled for the express purpose of obtaining the volatile oil, a greater per centage than the above would be produced.

Secondly, The natural products known under the names of naptha petroleum of Malta (mineral pitch), asphaltum and bitumens; whether these matters are found in a mixed state in sandstone, schist or limestone, or

only in a liquid state, or procured by the distillation of these mineral products.

These matters are all formed of carbon and hydrogen, but can only be employed after being rectified, so as to boil at about 212° of Fahrenheit.

Thirdly, The oil obtained by the distillation of caoutchouc, the first oil that comes over in this distillation, at the ordinary temperature, possesses a considerable illuminating power. I also employ any other oils which are very rich in carbon, and volatile enough to boil at 212° Fahrenheit.

The gas which I render luminous by the addition of any of these oils, is either pure hydrogen, or a mixture of hydrogen, carbonated hydrogen, and carbonic oxide.

I obtain pure hydrogen by the processes described in all treatises of chemistry, either by the decomposition of water, by means of iron or zinc and an acid, or by means of iron at an elevated temperature.

The gas which I prefer is that obtained in passing steam over red-hot charcoal reduced to a state of dust or powder, or over red-hot coke. The gas is a mixture of hydrogen, carbonic acid, carbonic oxide, and carburetted hydrogen, in variable qualities, according to the mode of operation. When the apparatus is only gently heated, there are produced hydrogen, much carbonic acid, and a small quantity of carbonic oxide; when, on the contrary, the apparatus is properly heated, and if the gas passes over a great excess of *incandescent* charcoal, before it arrives at the gasometer, it will produce hydrogen, much carbonic oxide, and little or no carbonic acid.

This gas may be produced in retorts similar to those used for making coal gas; but I prefer an apparatus consisting of one or more retorts, with a partition in the middle through the whole of the length. These retorts, filled with charcoal, are placed horizontally in a furnace, and so disposed, that the steam of water passes through the whole length of the under half of the retort, and returns through the whole length of the upper half, into a pipe leading to the gasometer. This mode is adopted, in order that the water may be forced to pass through a great excess of red-hot charcoal; and thus produce the least possible of carbonic acid, and the greatest quantity of carbonic oxide. Instead of the partition above named, retorts may be connected together with pipes, so as to obtain the same effect. The retorts may also be placed vertically; in this case, receivers or vases holding charcoal should be adapted to the upper end, closed hermetically, and thus furnish a supply of charcoal to the retort as it is wanted.

When the gas is thus prepared, there is no occasion to wash it, as it will be then almost entirely composed of hydrogen and carbonic oxide, in nearly equal portions, and a certain quantity of carbonated hydrogen.

To render the gas luminous, a current from the gasometer is passed into a vessel containing one of the volatile oils mentioned above. A part of the oil is converted into vapour, and carried off by the gas; and even before the gas has taken off enough to be saturated, it has acquired a luminous quality, sufficient for the purpose of lighting. When the temperature of the atmosphere is below 60°, the vessel containing the oil must be warmed until it has attained that temperature; which may be done by a small pipe from the gasometer placed under it, and firing the gas, or by keeping the vessel in warm water, maintaining it at the temperature of 60° at least.

The vessel containing the oil ought to be so arranged, that the gas which arrives may always take up the same quantity of volatile oil, which then passes into the service pipes for use.

The volatile oil may be mixed with the gas on its passage from the re-

torts to the gasometer, or in the gasometer itself; but I prefer the first method as the most advantageous. One pound of charcoal will produce at least fifty cubic feet of gas, and each cubic foot of gas requires from forty to fifty grains of the oil distilled from coal tar; two pounds of water furnishes, by its decomposition, about 800 gallons of gas.

I claim as my invention, the method of decomposing water by charcoal, so as to be free from carbonic acid without washing, which previously was always indispensable.

I claim, also, the having ascertained, by direct experiment, the chemical and physical qualities of the volatile oil necessary for rendering water-gas luminous, and support the changes of temperature, inasmuch as they must be in the state of a sesquicarburet, and boil at a temperature inferior to that of water.

I also claim as new, the having determined the quantity of volatile oil necessary to be combined with a given quantity of water-gas, to render it highly luminous.

I likewise claim as my invention, the method of combining the volatile oils and the water-gas, as well as the temperature at which those oils should be maintained, in order to their being taken up in a sufficient quantity by the gas before it passes into the service pipes. Ibid.

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### *Improvement in Leather.*

A patent was granted to Thomas Edmonds, for his invention of a certain process or method of manipulation and treatment for the preparation of leather, whereby it becomes less pervious to water; and preserves better its pliability during use, than does leather prepared by the ordinary means. —[Sealed 22d May, 1834.]

The Patentee says, I subject leather as it has been previously prepared by tanning or tawing, to the processes and treatment as hereinafter set forth.

For the first operation, I dissolve in three gallons of water, alum four pounds, gum arabic, gum tragacanth, of each two ounces. Apply this solution, at nearly boiling heat, with a sponge or soft cloth to both sides of the leather, in either a tanned or tawed state. Whilst the leather is still soft and damp, it must be pressed for a few hours betwixt hard and smooth surfaces; the degree of pressure being made greater or less, according to the substance, kind, and quality of the skin or hide: such continued pressure may be made betwixt plates of glass or polished metal, or betwixt slabs of marble, the pressure being effected by means of weights or screws. When removed from this kind of pressure, the leather should be passed repeatedly through a rolling machine; one of the cylinders of which should be heated by steam, or other well-known means, and the other kept cool: the degree of pressure betwixt the cylinders should be adjustable by means of screws, cams, levers, or wedges, so as to accommodate it to the thickness of the skin; this will give firmness or closeness to the leather.

For the second operation: liquefy by heat, of hog's-lard and deer suet, each four pounds, and melt together also by the aid of heat, of the cleanest resin, white bees-wax, and Burgundy pitch, each one pound and a half, in one pint of pale sperm oil: mix the two quantities of liquefied matters together whilst hot, and strain the whole through a fine sieve, adding, at

intervals, whilst it is passing through the sieve, one pint of spirits of turpentine, and subsequently, half a pint of spirits of wine; then simmer the whole together gently, and apply it in a warm state by means of a brush or mass of fine cloth to the dressed side of the leather, until the surface is well covered. Whilst the leather is still moist, pass it through rollers as before, until it becomes quite dry. For black leather, mix together two ounces of nitrate of silver, and four ounces of Prussian blue, each pulverized, and four ounces of lamp-black; add these ingredients to the composition of resinous and unctuous matters, before passing it through the sieve. If the leather is intended to be of any other colours, suitable pigments or colouring matters, in place of the above, must be employed.

For the third operation, triturate together burnt alum, chalk, or pipe-clay, and steel filings, of each four ounces, and pass the powder through a very fine sieve: with a flattened face of a piece of pumice stone, or other porous material rub some of the above powder on the dressed side of the leather, the skin being laid upon a slab of marble, or plank of smooth hard wood; the rubbing being continued until the surface becomes clear and polished.

Lastly, mix a portion of such colouring matter as corresponds with the colour of the leather in preparation, with a solution of white wax, in spirits of turpentine, and brush some of this in a liquid state slightly over the face of the leather; and, again, pass it through the rollers, or betwixt the pressing plates, and then the process will be completed. Ibid.

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## *Lighting with Gas.*

A patent was granted to Michael Donovan, for his invention of an improved method of lighting places with gas.—[Sealed 6th October, 1830.]

This invention consists in giving to certain inflammable gases a luminous power, which they are not found to possess in their natural or pure state. For instance, pure hydrogen gas, though highly inflammable, possesses but slight illuminating properties; it is only when combined with carbon that it becomes available for the purposes of illumination.

The Patentee also mentions carbonic oxide as a gas similarly circumstanced, and also, the gas produced by passing water or steam over red hot coke.

In order to give a higher degree of luminous power to these gases, it is necessary to unite them chemically with carbon in a state of vapour; and this is proposed to be done by combining the vapour produced from a combustible distillation of such substances as turpentine, or the resinous parts of coal tar or naptha.

These fluids, previously to their being applied, must be well freed from acidity, by washing in water containing pulverised chalk, or from ammonia, by acid, diluted with water.

The combination of the hydrogen and the carbon is to take place at the jet or burner, and which is to be effected by causing a small quantity of the turpentine, or other fluid containing carbon, to be led up to the burner by capillary attraction.

Various modes of effecting this object might be resorted to. The Patentee proposes to conduct pure hydrogen, or any of the gases which are to be employed, through tubes from a generator, in any of the ordinary modes, to

a jet or gas burner; and to place in immediate connexion with this burner a coil of fine wire, or fine wire gauze,—to communicate the turpentine, or other carbonaceous liquor, to the coil of wire by any convenient means, so that the liquid, rising by capillary attraction, may be evaporated by the heat as it approaches the burner, and there mixing its vapour with the pure hydrogen, give that carbonaceous or illuminating property to the gas which is required.

The Patentee suggests, as a convenient mode, that a cylindrical tube, having many holes perforated through it in lateral directions, shall be placed perpendicularly within the tube, which conducts the hydrogen gas to the jet or burner; that round this tube several folds of fine wire gauze shall be coiled, and that by a cock introduced into the side of the tube, small quantities of the spirit of turpentine or naptha shall be, from time to time, delivered on to the coil of wire gauze, where it will gradually ascend by capillary attraction;—that the pure hydrogen gas shall be allowed to pass up the tube in immediate connexion with the coil of wire gauze, and being ignited at the top of the burner, will communicate sufficient heat to evaporate the spirit of turpentine or naptha from the wire gauze, and cause its vapour to combine with the hydrogen gas at the upper part of the burner before it becomes ignited.

In this way, and in any other way that may be found convenient, the Patentee proposes to give carbon or other illuminating properties to pure hydrogen, or any other gas which, though combustible, burns with a dim or pale light, and thus effects his "improved method of lighting places with gas."

Ibid.

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### *Printing Silk, Cotton, &c.*

A patent was granted to John Budd, for a certain improvement, or certain improvements, in printing silk, cotton, calico, or other fabrics, and in the manufacture of blocks, cylinders, or rollers, used for such purposes.—[Sealed 27th January, 1835.]

The Patentee describes his improvements in the following words:—"My invention consists in the substitution (in the printing of silk, cotton, calico, or other fabrics) of engraved plates, blocks, rollers, or cylinders of zinc, alloyed with tin, instead of plates, blocks, rollers, or cylinders of copper, brass, &c. The chief advantage and improvement arising from the use of such plates, blocks, cylinders, or rollers of zinc, alloyed with tin, consists in their great economy, as their first cost will be considerably less than the present first cost of copper plates, blocks, rollers, or cylinders; and the loss, when worn out, will be much less than the loss at present incurred in the resale (as old metal) of worn-out coppers or brass plates, blocks, cylinders, or rollers.

"Another improvement and advantage arising from my invention, consists in the increased facility and economy with which such rollers of zinc, alloyed with tin, can be manufactured, compared with copper rollers.

"The zinc, which should be obtained as pure as possible, after being melted in the usual way, should receive the addition of tin. The proportion of tin which I have found to answer best is, ten parts of tin to one-hundred parts of zinc; but these proportions may be varied advantageously, according to the quality of the metals. The metal, or alloyed metal, after a due mixture has been effected by stirring, should be poured into moulds

of sand, of the necessary length and shape. It may be cast into hollow cylinders, by employing a core, and the metal will be found sufficiently solid. These cylinders, blocks, &c., are to be turned, hollowed, and fitted to mandrils, or flatted for plates; the surface hardened by hammering, planished, burnished, engraved, &c. &c., in the usual way of preparing metal plates and rollers for printing. I claim, therefore, as my invention, the exclusive right to employ and to manufacture, in the way I have described, plates, blocks, cylinders, or rollers of zinc, alloyed with tin, for the printing of silk, cotton, calico, and other fabrics." Ibid.

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### *India Rubber Cloth.*

An interesting report of a trial between Mr. Macintosh, the patentee for the application of a solution of India-Rubber in coal-oil, to cotton and other fabrics for the purpose of obtaining a cloth at once perfectly flexible, free from smell and entirely water-proof,—and Everington & Ellis, and others acting in concert with them, who had infringed the patent, is given at large in the November and December Numbers of the Repertory of Patent Inventions. The patent was taken out in 1823 by Mr. Macintosh, of Glasgow (now of Manchester,) a well known and very ingenious manufacturing chemist, and was of course within two years of the expiration of its term. Several years elapsed before the patented article came into extensive use and afforded profit to the inventor. At present the demand for it is very great, and the quantity manufactured in Europe and in the United States very extensive. The cause of the patentee was sustained by highly respectable witnesses, among whom were Professors W. T. Brande, J. F. Daniell, J. T. Cooper, and Dr. Turner; Richard Phillips, Arthur Aikin, Alexander Gardener, and J. G. Children. The facts were substantiated that, prior to the date of the patent, no person had used coal oil as the solvent of caoutchouc and applied it to the purposes of a material for water proof clothing, and that the oil or volatile inflammable liquid, which is one of the products of the distillation of coal at the gas factories, was, before this application of it, considered very much as a waste material or refuse. It is the only material which can be cheaply obtained that answers the purpose of a perfect solvent for India-Rubber.

On the part of the defendants is was shown that the native milky juice of the plants, which, on desiccation, yields caoutchouc, has been long applied in South America to the same purpose of cementing two surfaces of cloth to each other, and that outer garments had been occasionally made of such water proof fabric.

Dr. Hancock, one of the witnesses for the defendants, had seen water proof articles exhibited for sale in Demerara in 1812 and 1813. Socks made of this article had also been sold in England in 1821. It appeared, however, on the trial, that there was a repugnance to the use of the South American cloth on account of its unpleasant odour. George Green, the celebrated aeronaut, testified, that he had long used a solution of India-rubber in *oil of turpentine*, as a cement for his balloon fabrics, and that the same material had been worn as a cloak.

No one had appeared as a rival to Mr. Macintosh for more than ten years after the patent was taken out, and no other cloaks possessing the

qualities described in his specification were exposed for sale. In 1824, he had an order from the Ordnance Office to the amount of £500.

About twelve months ago the defendants (said the Attorney General) took up the manufacture of the article under the pretence that they had bought some man's patent, and they labelled their cloaks: *Fanshawe's improved patent India-rubber water-proof Cloth.* But there is no such patent as Fanshawe's in existence; this is pure invention.

At the conclusion of the argument, his Lordship (the Vice Chancellor) commenced summing up, when the Jury intimated they were satisfied, and found for the plaintiff.

In this trial, as in those which Boulton & Watt triumphantly sustained in the defence of their patent, and in others of a like nature, there can be no question that the cause of *justice* in its decision in favour of individual *rights*, will ever be found in consonance with the highest evidences and most rapid advances of national prosperity. G.

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"*On the application of Glass as a substitute for metal balance-springs in Chronometers.*" *By Messrs.* ARNOLD *and* DENT.

In their endeavours to determine and reduce the errors arising from the expansions of the balance-spring of chronometers consequent on variations of temperature, the authors came to the conclusion that there exist certain physical defects in the substances employed for its construction, beyond the most perfect mechanical form that can be given to it, which interfere with the regularity of its agency: so that however exquisite may be its workmanship, and however complete its power of maintaining a perfect figure when in different degrees of tension, yet the imperfect distribution of its component parts may give rise to great incorrectness in its performance. Hence the balance-spring not only should be made of a substance most highly elastic, but its elasticity should not be given to it by any mechanical or chemical process: as a body in motion, it should be the lightest possible; and, as far as the case admits of, it should be free from atmospheric influence. Glass suggested itself as the only material possessing, in the greatest degree, all these desirable properties. Its fragility, although apparently a great objection to its employment, was found, on trial, to constitute no obstacle whatever; for it was found to possess a greater elastic force than steel itself, and thus to admit of greater amplitude in the arc of vibration.

It was first proposed to ascertain how far a glass balance-spring would sustain low temperatures; and it was found by experiment that it resisted completely the effects of a cold as great as that of + 12° of Fahrenheit's thermometer; thus satisfactorily removing any objection which might be brought against its use from its supposed fragility in these low temperatures. The next object of solicitude was to determine whether it would withstand the shock arising from the discharge of cannon in the vicinity; and its power of resisting concussions of this nature was fully established by experiments made with this view on board H. M. S. Excellent, at Portsmouth.

On comparing the performance of glass balance-springs with metallic ones, when the temperatures were raised from 32° to 100°, it was found that while the loss in twenty-four hours in the gold spring was 8′ 4″, that of steel, 6′ 25″, and that of palladium 2′ 31″, that of a glass spring was only 40″. These differences the authors ascribe principally to the different

degrees in which the substances had their elasticity reduced by an increase of temperature. As glass was thus found to suffer a much smaller loss of elasticity by this cause than metals, they proceeded to construct a glass balance suited to the correction of the small error still occasioned by this cause, employing a glass disc for this purpose. The compensation being completed, they next tested the isochronism of the glass spring, and it proved to be as perfect as any metallic spring. Chronometers thus constructed are now in course of trial at the Royal Observatory. In common with all other instruments of the same kind they have shown a disposition to progressive acceleration, the cause of which is but little known, but which appears to be influenced by the action of the air. L. & E. Phil. Mag.

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## Progress of Physical Science.

*Of the influence of different Winds on the Heights of the Barometer.*

As soon after the memorable discovery of Torricelli as meteorologists directed their attention to the observation of the barometer, they perceived that, *in general*, certain winds produced a rapid ascent of the mercurial column, while the opposite ones produced a contrary effect, in a manner as equally decided. The difficulty was, to determine the *numerical value* of these influences. It was necessary, in order to eliminate entirely all transient and accidental influences, and to obtain the true measure of permanent causes, to operate upon great numbers; it was necessary to obtain long series of good observations made in the same locality; it was necessary to group the winds according to their precise directions; and, finally, to separate effects purely thermometrical.

Burckhardt undertook this labour, availing himself of twenty-seven years of observations which Messier had made at Paris, from 1773 to 1801. If we designate by the letter H. the mean height of the barometer at Paris, that is to say, the height determined by the average of all the observations, the means corresponding to the different winds, according to Burckhardt's calculations, will be as follows:—

| | | mm. | Eng. In. | | | mm. | Eng. In. |
|---|---|---|---|---|---|---|---|
| South . . | H. *minus* | 3, 1 | (1·23) | North . . | H. *plus* | 2, 0 | (0·78) |
| South-west . | — | 2, 9 | (1·11) | North-east . | + | 2, 6 | (1·03) |
| West . . | — | 0, 4 | (0·16) | East . . | + | 1, 1 | (0·39) |
| North-west . | *plus* | 1, 3 | (0.51) | South-east . | + | 0, 8 | (0·31) |

It will be seen, from the mere inspection of this table, that the direction of the wind occasions a variation in the state of the barometer at Paris of $3^{mm}$, 1 (1·23 Eng. in) above the mean, and of $2^{mm}$, 6 (1·03 Eng. in.) below it, forming a total variation of $5^{mm}$, 7 (2·26 Eng. in.); and that the opposite winds, combined two by two, give a mean height which, in extreme cases, scarcely differs by half a millimetre (0·19 Eng. in.) from the mean of all the observations.

M. Bouvard has presented to the Academy the results of an investigation analogous to that of Burckhardt; it is founded on the observations of the barometer made at the Observatory of Paris from 1816 to 1831, and leads, in general, to the same conclusions. By assigning to the letter H. the signification which we gave it in the preceding table, we shall

have the following barometrical heights, corresponding to the different directions of the winds:—

| | | mm. | Eng. In. | Obs. | | | mm. | Eng In. | Obs. |
|---|---|---|---|---|---|---|---|---|---|
| South | H. *minus* | 3, 7 | (1·46) . | (2944) | North | H. *plus* | 3, 2 | (1·27) . | (2140) |
| South-west | — | 3, 0 | (1·18) . | (2847) | North-east | + | 3, 2 | (1·27) . | (1390) |
| West . | — | 0, 8 | (0·31) . | (3402) | East | + | 1, 7 | (0·67) . | (1248) |
| North-west | *plus* | 2, 0 | (0·78) . | (1533) | South-east | *minus* | 1, 7 | (0·67) . | ( 890) |

The daily observations at nine o'clock in the morning, at mid-day, and at three in the afternoon, have all concurred in the formation of these numbers. Almost exactly the same results will be obtained by employing only the maxima heights of nine o'clock, and the minima heights of three o'clock.

In this instance, as well as in the table of Burckhardt, half the sums of the heights corresponding to the opposite winds are nearly equal to H., that is to say, to the total mean. The highest mean effect of the wind is 6mm, 9 (2·73 Eng. in.), which surpasses the result afforded by the observations of Messier by 1m, 2 (0·47 Eng. in.)

Both these tables tend to establish a fact with which meteorologists cannot be too strongly impressed,—that in order to obtain in our climates the mean height of the barometer, it is indispensable to admit into the calculation an equal number of observations corresponding to winds of opposite directions.

The tables which we have just transcribed, suggest many scientific questions; they lead us to inquire in what manner this influence of winds on the atmospheric pressure, varies with the position of places, with their greater or less distance from the sea, with their latitude, &c. In the mean time, till data sufficiently numerous be obtained to enable us to attempt the solution of these various meteorological problems, I shall here present to the reader the results of two series of very accurate observations, which were communicated to the Academy by MM. Schuster and Gambart. The first were made at the School of Artillery and Engineers at Metz, the others at the Observatory of Marseilles.

*Observations at Metz, (Nine years.)*

| | | mm. | Eng. In. | | | mm. | Eng. In. |
|---|---|---|---|---|---|---|---|
| South . . | H. *minus* | 2, 4 | (0·95) | North . . | H. *plus* | 2, 4 | (0·95) |
| South-west . . | — | 2, 1 | (0·83) | North-east . . | + | 2, 1 | (0·83) |
| West . . . | — | 0, 6 | (0·25) | East . . . | + | 1, 0 | (0·31) |
| North-west . . | *plus* | 0, 3 | (0·11) | South-east . . | *minus* | 0, 8 | (0·31) |

The difference between the extremes is sensibly less than in the observations at Paris. At the same time, it would be premature to draw general conclusions from this fact, which may perhaps be purely accidental.

The following seems more decisive:—

*Observations at Marseilles, (Five years.)*

| | | mm. | Eng. In. | | | mm. | Eng. In. |
|---|---|---|---|---|---|---|---|
| South . . | H. *plus* | 0, 0 | (0·00) | North . . | H. | — | — |
| South-west . . | + | 0, 7 | (0·27) | North-east . | | — | — |
| West . . . | *minus* | 0, 5 | (0·19) | East . . | *plus* | 0, 2 | (0·07) |
| North-west . . | — | 0, 9 | (0·35) | South-east . | + | 0, 5 | (0·19) |

Although this table is incomplete, and founded on observations of only five years' continuance, and although the north and north-east winds are entirely omitted, there results from it no less important a consequence than this,—that if the direction of the winds exercises, at Marseilles, any influence on barometrical heights, that influence is very slight, and ought not

always, in the case of winds of similar denominations, to have the same sign as in the north of France. Thus, while at Paris the south-west wind depresses the barometer considerably below the mean, its influence at Marseilles is *positive;* on the other hand, the north-west wind, which causes a considerable rise in the barometer at Paris, is that which produces the lowest depression at Marseilles.

When observations such as these have been made at many different places, they will probably place meteorologists in a condition to explain a phenomenon which has hitherto baffled all their efforts. Mag. Pop. Sci.

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*Height of Waves, Hydrostatic Pressure from them. By* W. W.

In the months of June and July, 1830, I happened to be on the Island of Ascension, employed on a particular service. A long swell began to set in from the S. W., which was at right angles to the direction of the S E. trade-wind. These rollers soon cut off all communication with the shore, by breaking violently on the beach. Being on shore, an opportunity offered for ascertaining the height of these antarctic waves. A buoy had been laid down just 1700 feet from the crane at the landing stairs: I stood near the crane with my eye elevated twenty-four feet above the ordinary sea-level, and observed that the summits of the waves, as they reached the buoy, were in a straight line between my eye and the visible horizon. Taking the visible horizon from a height of twenty-four feet, to be at a distance of 34,200 feet, we may determine the height of the waves by the following proportion, viz., The distance of the visible horizon will be to the height of the eye above the sea-level, as the distance from the wave to the visible horizon, to the height of the wave above the level of the sea; or, 34,200 ft. : 24 ft. : : 34,200 ft. — 1700 ft. : $22\frac{3}{4}$ ft. nearly; making the whole height, from the summit to the bottom of the wave, $45\frac{1}{2}$ feet.

The conditions under which these waves reached Ascension merit consideration. My notes were taken on the first of July, 1830. It was then the winter season in the southern hemisphere: the barometer had fallen one-tenth of an inch, (an unusual circumstance there.) The swell came from the S. W. quarter, and at right angles to the direction of the trade-wind, and the waves raised by it, the "rollers," that then reached Ascension, must have been raised by a gale of wind from the S. W., without the limits of the trade-winds; probably in the neighbourhood of the Falkland Islands, or near Cape Horn, and at a distance from Ascension of three or four thousand miles. Their height must have been diminished by crossing the variable latitudes, and traversing the S. E. trades. On the other hand, these long waves, on reaching within five or six miles of Ascension, passed in about ten minutes from a depth of 1000 fathoms into 10 fathoms, and thereby met with retardation. They were, therefore, crowded near the beach, and broke with great violence, carrying away vast quantities of sand into deep water.

We have seen, then, an instance where a wave of no great magnitude, was found to be at least twenty-two feet above the ordinary sea-level, after having traversed a space of several thousands of miles beyond its native seas, and overcoming obstacles in its progress, instead of being urged on by the wind! We may, therefore, conclude, that the actual height of waves, in an open and deep sea, and in hard gales of wind, must be much greater than twenty-two feet; perhaps thirty or thirty-five feet. If so, the actual height of a wave, above the adjacent depression, must equal 60 or 70 feet.

The force exerted, and the effects produced by waves, are very extraordinary. It has been asserted, that the sea has broken over the lantern of the Eddystone Lighthouse. It is very certain, that during the night of the 26th November, 1703, the Eddystone Lighthouse was completely swept from its foundation, and carried away! The changes produced in hydrostatic pressure, by waves in a gale of wind, have been well exemplified among the huge blocks of marble composing the Plymouth Breakwater. Here stones, weighing several tons each, have been raised up out of their beds in the solid structure by a vertical force, in consequence of a huge wave behind the Breakwater transferring an almost instantaneous excess of pressure throughout, the fluid filling the openings among the stones of the fabric. The projectile force of waves is also very great: thousands of stones, five or six tons each, have been rolled up the sea-front of the Breakwater, and tumbled over it into the Sound.

These stones have been seen, in a gale of wind from the S. W., rolling up and down by successive waves; and alternately reaching the summit, have rested there for a moment, till some "giant surge" should send them from their resting-place into the Sound.

Another example of the force of waves may be seen here. A large flat block of hewn stone now lies near the harbour-master's house at Boveysand, which was torn from its place in the pier by a wave, and thrown sixteen or eighteen feet above high-water mark, where it remains as a record of what has been effected, and what may again be expected, from the force of the waves and the raging of a storm.

*Devonport, 10th Nov.*, 1835. Lond. Naut. Mag.

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*Physical character of Conicine, the active principle of Hemlock. (Conium Maculatum.)* By Boutron Charlard and O. Henry.

These Chemists appear to have been very successful in obtaining large quantities of *Conicine*, (a term which they adopt from Berzelius, in preference to all others.) The object of their researches was to settle the question whether the objection of Deschamps to the conclusion of Geiger (viz. that the Conicine of Geiger owes its alkalinity to Ammonia, and that if the active principle of Hemlock is an alkaloid it still remains to be isolated) is well founded or not. We need not here detail the process by which they procured the narcotic principle, nor the precaution used to ascertain its freedom from Ammonia. The conclusions they arrive at are:

1. That there exists in Hemlock (*conium maculatum* of L.) and in the seeds of that plant, a peculiar volatile principle which is very poisonous.

2. That this principle, when pure and exempt from water, is in the form of a liquid of an oily appearance, lighter than water, and possessing in a high degree the property of saturating acids and forming cristallizable salts.

3. That contrary to the opinion put forth by some chemists, this alkalinity is inherent and is not owing to the presence of ammonia.

4. That this principle, which is the first example of a liquid, volatile, vegetable alkali, and which has been designated by the several names of *Conincientine*, *Coneine*, and finally *Conicine*,* ought now to be ranked among organic salifiable bases.

* We prefer the more analogical term proposed by Dr. Wood in the U. S. Dispensatory—*Conia*. Trans.

In reply to a subsequent objection of Deschamps that its alkalinity is owing to the caustic potash or soda used in its preparation, they assert that it may be obtained by Calcined Magnesia and even by neutral acetate of Lead.

It appears also that *Conicine* has been analysed by Liebig, and found to consist of

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| Carbon, | 66.91 |
| Hydrogen, | 12.00 |
| Azote, | 12.80 |
| Oxygen, | 8.29 |
| | 100. |

Annales de Chemie, Avril, 1836.

G.

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*On the latent heat of Carbonic Acid Gas.* By M. Bischoff.

In decomposing Carbonate of Lime by heat in a gun barrel, I found the end of the barrel at 144½ Far. while the current of gas indicated only 88¼F. If we suppose the temperature to which the Carbonate of Lime was exposed to be equal to the melting point of gold, or about 2500° or 2600° F. the gas would have rendered latent 2430 to 2500° Far.

When chalk is decomposed by weak sulphuric acid the mixture marks 122° F. and the gaseous current 86°. When the acid is concentrated, the mixture is 212° F. and the current 133°.

Ann. de Pog. in Ann des Mines.

G.

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*On the use of Ether in Analyses.* By M. Dobereiner.

If to a solution of chloride of manganese and cobalt in alcohol, fifteen to twenty times its volume of ether be added, all the chloride of manganese will be precipitated and the liquid becomes of a beautiful blue. In adding water, the chloride of cobalt is precipitated of a rose colour; and by redissolving in alcohol and employing ether again we may separate the whole of the chloride of manganese.

Ether has a strong tendency to form a special combination with twice its volume of alcohol, and this tendency may frequently be turned to profit in chemical analyses.

An alcoholic solution of hydrate of potash, which contains .25 to .30 of water is entirely decomposed by ether, so that the potash separates in the state of an aqueous solution; but if the alcoholic liquor contains no water, the ether does not separate the potash, and the separation is effected only by adding water to the mixture.

If a mixture of nitrate of lime and nitrate of strontian be treated with alcohol, and that independently of the first salt a little of the second be dissolved, the whole of the latter may be precipitated by adding ether and allowing the liquid to remain some time at rest.

Ann. des Ph. in Ann. des Mines 1836.

G.

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*Promotion of the Germination of Seeds.*

"Having procured, while in England, seeds of various species of the Australian Acáiæ, and sown them immediately on my arrival at the Cape [of

Good Hope], I was much disappointed at the apparent failure of many of them, but have found several of them vegetating after being three years in the ground, during which period they were duly attended in weeding and watering. Seeds, also, of *Acàcia* longifòlia, saved at the Cape, and sown ten days after gathering, showed the same tardiness in vegetating. This circumstance led me to consider the best mode of treatment in trying experiments with the Cape species of *Acàcia*, and other South African Leguminòsæ; and I find that nearly the whole of this order thrive better by having water heated to 200°, or even to the boiling point of Fahrenheit's thermometer, poured over them, leaving them to steep, and the water to cool for twenty-four hours. Where there is a numerous collection, and the quantity small of each species they may remain in the papers."—*J. Bowie, Cape of Good Hope, Feb.* 16, 1831. (*Gard. Mag.*, vol. viii. p. 9.)

"Great degrees of heat, short of boiling, do not impair the vegetative power of seeds; nor do we know any degree of cold that has such an effect. Those who convey seeds from distant countries should be instructed to keep them dry; for, if they receive any damp sufficient to cause an attempt at vegetation, they necessarily die, because the process cannot, as they are situated, go on. If, therefore, they are not exposed to so great an artificial heat as might change the nature of their oily juices, they can scarcely, as several cultivators have assured me, be kept in too warm a place." (*Smith, in his Introduction to Physiological and Systematical Botany,* 6th ed., p. 81.)

Mag. Nat. Hist.

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### *Valuable Acid for Engravers.*

M. Deleschamps has written to the *Académie des Sciences* that he has accomplished the solution of the following problem, for every kind of biting acids employed in engraving. *To obtain a clean and deep line, without sensibly enlarging the furrow in ordinary engraving, and without eating away the sides of the subject in engraving in relief.* He uses a composition of acetate of silver, and hydrate of nitrous ether. Immediately after the contact, the acetate is precipitated into the lower part of the furrow, where it produces a rapid and energetic action. The upper parts of the furrow are occupied by the nitrous ether, and preserved by its presence. Mag. Pop. Sci.

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## Progress of Civil Engineering.

### *Thames Tunnel.*

As it may be interesting to our readers to know what progress has been made in this great work, we beg to present them with an extract from the last report of the directors. We have also the pleasure of adding, that the work continues advancing with every prospect of a successful termination. Since the last report, 60 feet of the brickwork of the tunnel have been completed, which, added to the quantity previously finished, makes a total of 660 feet. By this addition, the tunnel is now carried beyond the centre of the river, and is steadily approaching the Wapping shore.

As this important work now occupies a large share of public attention, the directors take advantage of the opportunity at present afforded them, to place before the proprietors a few facts connected with its progress and

present state, in order to enable them to form correct opinions of the undertaking.

In the first place, it is of great importance to keep in mind this fact, viz. that when the works were stopped in 1828, that stoppage was occasioned by no difficulties of an engineering nature whatever, but solely on account of the original capital of the subscribers being exhausted. And it is of still greater importance to remember, that at that time, about 599 feet out of 1300 feet, which is the extreme length of the horizontal roadway and the shaft, were completed for the sum of about 120,000*l.* only. The directors never received, of the original subscription, more than 182,000*l.*; the difference between this and the former sum being 62,000*l.*, was, as has been frequently stated to the proprietors at their annual meetings, absorbed by the purchase of land, the cost of engines, machinery, stores, buildings, parliamentary and other expenses (including the cost of maintaining the works during the time they were suspended, a period of nearly seven years), and by the extra expenditure occasioned by the two irruptions of the river. These expenses are only thus generally alluded to, because they have all been submitted in detail to the proprietors.

The experience hence gained of the nature and cost of the work, enabled the engineer to form a practical basis on which to found an estimate for the execution of the remaining half of the tunnel, and which has been admitted to be a sound basis for the calculation by successive administrations, to whom application was made for an advance in Exchequer Bills, in order to enable the company to proceed with the undertaking.

The directors, before they proceed to give a particular detail of the advance made towards the completion of the tunnel since the annual meeting in March last, beg to remind the proprietors, that in their annual reports of 1835 and 1836, they endeavoured to guard against the undue expectation of progress in the first year, and they did so from three distinct considerations:—They were assured by the Company's engineer, Mr. Brunel, that to remove the old shield, and replace it with a new one, would be the work of great expense, of slow progress, and of great danger. The expense, however, is one properly chargeable upon the whole work to be done, and must not be considered as exclusively belonging to that which has been recently completed. They are aware also from experience, that when this hazardous work was effected as it was with unexampled skill and presence of mind, that the knowledge of a vast and complicated machine, and the mode of working it, could only be acquired slowly; and that hence delay in the rate of progress was incidental to the recommencement of the works, and was to be expected for some time afterwards. Added to which, these difficulties were to be encountered under the deep part of the river, where its bed was known to be most unfavourable to the labours of the miners, and most susceptible of the fluctuating influence of the tide. Notwithstanding these difficulties, the tunnel has advanced to the extent already mentioned; and though they have retarded the progress of the work, yet the miners have acquired both confidence and familiarity in the discharge of their duties, and in the management of every part of the shield; and hence, it may be fairly anticipated, that when the deep part of the river is passed, and where none of the greater difficulties of the undertaking may make speed of less importance than safety to the men and security to the works, a quicker rate of progress will become practicable.

It may here be mentioned, that a constant and accurate inspection of the ground in advance, is maintained by means which are found perfectly effi-

cient, and which have enabled the engineer to anticipate and avert those dangers which formerly would, in all probability, only have preceded an irruption. The accuracy of the second series of borings in the river, which was made in 1827, under the superintendence of the then resident engineer, Mr. I. K. Brunel, has been hitherto practically demonstrated by the knowledge of the ground, obtained in the course of the actual excavation. This second series took place in consequence of the discovery made in the progress of the works of the inaccuracy of the first borings, which were made under the directon of Messrs. Jolliffe and Banks, and laid before the directors, shortly after the formation, but previous to the incorporation, of the Company.

To enable the proprietors now to form an opinion of the state of the works, the directors submit the following details under distinct heads, which are in substance the weekly reports of Mr. Brunel to the directors.

1st. The new shield has fully answered its purpose, and has enabled the work to proceed through some portions of the ground in almost a fluid state. It is greatly superior to the old one. The resistance against which it has to exert its power, is computed at about 3000 tons vertical and lateral pressure, nevertheless, it possesses both facility and precision of movement. Some idea may be formed of the extent of the excavation which it enables the miners to carry on through ground of the consistency previously described, and which it preserves until the brickwork is completed, when it is known that the whole area of the ground, equal to 2000 superficial feet, over the whole of which vents are open for the infiltration of water both from the river and land-springs, which latter have been found most copious, and sometimes a source of considerable alarm and difficulty. The total area from over which such vents are opened, and through which infiltration takes place, exceeds 75,000 superficial feet.

2nd. The reservoirs and drains, the completion of which was spoken of in the last report, have been of great value. They have, under the largest influx of water, given facilities to the progress of the miners unknown before. Formerly, forty hand-pumpers, in gangs of twenty each, besides artificers in conjunction with them, were required, who greatly impeded the miners and bricklayers, and who, owing to the adoption of the reservoirs and drains, are now dispensed with.

3rd. State of the ground. Under this head the directors are desirous to state the obligations the Company are under to the Right Honourable the Lord Mayor (Mr. Alderman Copeland, M. P.) and the Navigation Committee, and also the Harbour Masters acting under them. The manner in which they have at once discharged their duty to the public, whilst they have given every possible facility to the proceeding of the engineer, calls for the strongest expressions of obligation on the part of the directors and the proprietors at large. On the suspension of the late works, a temporary covering of made ground was raised over and around the head of the tunnel consisting of gravel and clay; but in consequence of the long cessation of the works, the city authorities ordered this covering to be removed, in order to restore the navigation of the river to its usual state, which was accordingly done. Upon resuming the works, and on examining the ground, the favourable state of it enabled the engineer to proceed for a time without again resorting to the protection which it afforded; it was, however, thought prudent to obtain from the Lord Mayor permission to resort to this plan when necessary, as a precautionary measure against the great influence of the tides whilst the tunnel is being constructed under deep water. The

influx of river water is discovered by its temperature, as well as by the increased quantity pumped up by the engine; and it is found invariably, that a timely resort to this expedient immediately reduces the quantity, and brings it under control. The precaution is, therefore, one essential, in the opinion of the engineer, to the security and progress of the works.

4th. Rate of progress. Since the annual meeting, 60 feet of brickwork have been completed, which, added to the 10 feet (always occupied by the shield) excavated, makes a total of 670 feet, notwithstanding the difficulties which had to be encountered on the resumption of the works, which have been already alluded to in a former part of this report. As the tunnel approaches the opposite shore, the difficulties of the undertaking will decrease. The thickening of the crust of earth, or the bed of the river over the head of the miners, will render the more rapid advance of the shield perfectly practicable; and as the works will then be carried on under shallower water, they will be less influenced by the tides.

In a report made on the 24th of August to the directors, Mr. Brunel says, "Contrasting our present state, however, with almost the whole course of June last, it will be seen that we have gained considerably in every respect. On many occasions in June, we were obliged to block up and timber the top boxes, and even to suspend our proceedings until we could approach as it were the top polings, and probe the ground; but since, and from the auxiliary means which I adopted on the 2nd of July, and made an application on that day, not one single instance is recorded of the boxes being blocked up, or of ground breaking in; on the contrary, the ground which could not be worked before, and wherein a pricker entered seven feet a-head, was worked with perfect security. We may anticipate that we shall gradually improve in progress. The auxiliary means alluded to in the foregoing report, and which can only be generally described, consist of a system of pinning and isolating a portion of ground, which is then removed without disturbing the contiguous portion from which it is taken, and which has enabled the work of excavation to proceed under the most formidable circumstances. This system, combined with a mode now adopted, of at once conveying away the land-springs and directing their course to the reservoirs, instead of attempting to stop their influx, has enabled the miners to proceed where difficulties have appeared at first almost insuperable.

Accounts of expenditure. A statement of the receipts and expenditure of the half year, ending on the 30th June last, is annexed to the report; which statement, added to those which have hitherto been laid before the proprietors, will furnish them with the expenditure which has taken place by the company up to Mid-summer last.

The directors have thus endeavoured to lay before the proprietors a general view of the works, together with a statement of the expenditure of the Company. They regret to add, that owing to the illness of the family of the late resident engineer, Mr. Beamish, he has been unavoidably obliged to resign his situation, which has deprived Mr. Brunel of the zeal and professional assistance so ably afforded him by Mr. Beamish. The directors, on the recommendation of Mr. Brunel, have made a temporary arrangement with one of their assistant engineers, as it appeared that the duties of the office might be susceptible of a new and better distribution.

In Mr. Brunel, the directors continue their unabated confidence; and in conclusion, whilst they remind the proprietors that the work is one not yet free from both uncertainty and danger, they still desire to reiterate their

opinion, that, at no very distant period, this great undertaking will, in spite of opposing difficulties, be completed, and a communication made between the shores of one of the deepest parts of the river, where, within a small space, the trade and navigation of London may almost be said to be concentrated: and that, in all probability, this communication will be made at less than half the expense of any communication for similar purposes within the range of the metropolis. Jour. Arts & Sciences.

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### *Steam Carriages on Common Roads.*

A committee of the British House of Lords have, by their report to the House, objected to the reduction of prohibitory tolls on such carriages; on the ground of the danger in frightening horses, of setting fire to buildings, &c., of the greater skill required to manage such locomotives than those on railways; and more especially from the opinion that such enterprises cannot become profitable to those who engage in them, and that, therefore, any encouragement on the part of the Legislature would only give rise to wild speculations, ruinous to those who pursue them. G.

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### *Aeronautic Observations.*

Mr. Green, who recently ascended in a balloon with Lord Clanricarde, observed that surveyors and architects could with greater facility take plans of noblemen's estates by ascending in a balloon, as they could have a bird's-eye view of every locality, and if they only once adopted that method they would never relinquish it. Since the suggestion, an artist named Burton called on Mr. Green to obtain from him the plan of a balloon constructed so as to act in the above way, it being connected to the car by a swivel. The inventor proposes to build a wagon, for the purpose of fastening a balloon to it, which, when filled with gas, which can be done in various parts of the country at gas company's gasometers, may be conveyed to any place a surveyor requires, where, on a calm day, he can take plans, carrying with him the proper instruments. The balloon will then be fastened by ropes to the spot most favourable for observations, and raised to an elevation of 300 or 400 feet, as necessary. In this way a bird's-eye view can be taken of any town or city. Mr. Green is willing at any time that his balloon, by way of experiment, may be made use of in that way. Lond. Mech. Mag.

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### *New Surveying Instruments.*

M. Lalanne, Engineer of the *Ponts et Chaussées*, in France, has laid before the *Académie des Sciences* three instruments for topographical surveying, which, if they accomplish all that the inventor promises, correctly and with facility, will be eagerly sought after. To the immense number of surveyors, who are about to commence operations in every part of the United Kingdom, under the numerous Railroad Acts which have passed this session, such instruments would be invaluable. They are, 1st, a Levelling Instrument, or Carriage, which it is only necessary to run over the ground, the levels of which are desired, and the section is at once obtained; 2nd, a Drawing Instrument, which lays down the plan of the ground; and can be mounted on the carriage of the Levelling Instrument; 3rd, a Power-measuring Instrument, or Dynamometer, which exhibits the effort exerted on every point of the line passed over. Mag. Pop. Science.

*St. Petersburg.*

Within the three last years, this capital has extended itself greatly. New streets have been erected in various directions, in parts which were formerly quite beyond the boundaries of the city; and numerous other improvements are in the course of taking place; one of which is to convey an abundant supply of water from the Neva to all parts of the town. The works of the St. Isaac's Church are now proceeding with great rapidity, no fewer than three thousand men being employed on them daily during the present summer. Of the twenty-four granite columns (each of a single piece, 42 feet high) which are to adorn the exterior of the dome, fifteen are already erected, and the remaining nine have been prepared at the quarries. At present, the forest of scaffolding which surrounds the edifice renders it impossible to judge precisely what the effect will be; yet there is little risk in predicting that, when completed, it will prove the most stupendous architectural monument of modern times; not, indeed, altogether the rival of St. Peter's at Rome, as far as depends upon actual dimensions alone, but eclipsing it both in splendour of materials and in grandeur of style.

Archit. Mag.

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*The General Architectural Improvement of London.*

We are happy to see that this subject is attracting the attention of Parliament; Mr. Alderman Wood has obtained a select committee to consider the propriety of a new street from Southwark Bridge to the Bank of England; another from Waterloo Bridge to the New Road; a third, from Lothbury to the Post Office; a fourth, from the Post Office to Smithfield; a fifth, from Holborn to the Strand; a sixth, through Southwark; a seventh, from St. Paul's to Blackfriars' Bridge; an eighth, from Oxford Street southwards; and a ninth, from Westminister Abbey to Belgrave Square. Sir Robert Peel hoped that an enlarged view would be taken of the subject, and that the house would not fall into the error it had committed with respect to railroads. Perhaps the best mode of proceeding with railroads would have been to appoint competent persons to survey the whole country, and to report upon the most eligible lines; but, though it was now too late to take that course, something of the same kind might be done, with a view to the contemplated improvements of the metropolis; and, before money of any kind were expended, some foresight ought to be used as to the future extension of London. If commissioners could be found, in whom the public would have confidence, for a rational and comprehensive plan, it would be a subject of much congratulation.

Ibid.

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## Mechanics' Register.

*Copper Ore raised in Cornwall.*

The quantity of copper ore raised at about eighty mines in the county of Cornwall, during the past twelve months, was 140,981 tons of 21 cwts., the average produce of which was 8¼, giving 11,639 tons 11 cwt. of copper; the average price for the ore was £6,17 per ton, amounting to £957,752,8,6. With three or four exceptions not one of these mines belong to a public company.

### *Mining in Cornwall.*

The steam engines now at work in the mines of Cornwall, are equal in power to at least 44,000 horses. One bushel of coal does as much work as sixteen bushels did in the earlier stages of the employment of steam power.

Newton's Jour.

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### *To prevent Milk from turning Sour.*

Add to each quart of milk about 16 grains of bi-carbonate of soda. It does not injure the taste of the milk, and aids remarkably the digestion of it. One of the large milk establishments of Paris has no other means of keeping the milk which remains, an advantage which is highly appreciated in large concerns of the kind.

Jour. de Connais, Usuelles.

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### *Irradiation of Light.*

It is a curious fact, that if the same letters of the same size precisely are painted on two boards, the one white on a black ground, and the other black on a white ground, that the white letters will appear larger, and be read at a greater distance, than the black. This is owing to what is called the irradiation of light. It depends on this, that the impression made on the bottom of the eye by bright objects extends a little wider than the actual portion of the organ struck by the light, and invading the space occupied by the darker objects, makes the brighter appear larger than they really are.

Railway Mag.

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### *Discovery of Roman Remains.*

A great many Roman remains have been recently discovered at Exeter; consisting it is said, of a complete Roman city below the western market, which has been lately excavated and rebuilt on a grand scale. The relics prove the existence of the ancient Isca of Ptolemy and Antoninus on this spot. They consist of more than 400 Roman Coins, of copper and silver, from Claudius to Valens; a very great quantity of the ancient red Samian pottery, sepulchral urns, amphoræ, pateræ, simpula, two curious lamps, lachrymatories, terracottas of great beauty, relating to mythological subjects, two sepulchral vaults, &c. The excavations are superintended by Captain Short, of Heavitree, who is considered an able and excellent antiquary.

Mining Journal.

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### *The New Vehicle Retarder.*

Much curiosity has been excited in Oxford by repeated trials of a new invention intended to regulate the speed of carriages when descending a hill, by means of which the coachman can instantly or progressively lock both the hind wheels. The apparatus was applied to a four-horse stage, which was loaded with passengers, and, on ascending or descending a hill, was found to answer all the purposes intended. The inventor then proposed that the coach should be taken down the hill without the horses, and it was frequently stopped while proceeding at the rate of twelve miles an hour. Many practical gentlemen had ample proofs of the principle of the invention by having the coach lifted up, and the two hind wheels allowed to turn free on the axle, when it was found that a two-pound weight, placed on the extremity of the wheel, would gently bring it round; but when the

first degree of retarding power was applied, it took a weight, so placed, of fifteen pounds to bring it gently round; the second degree, thirty-six pounds; the third degree, fifty-six pounds; and the fourth degree, three quarters of a hundred; but with this weight no one person was capable of moving either wheel on its axle. Mr. B. Pearson, organist of the city church, is the inventor.—*Oxford Paper.*

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*Effect of the velocity of air upon its use in smelting Iron.*

Mr. Teploff, one of the Russian mining corps, in an article on the improvements recently introduced into the smelting of iron in Russia, makes the following statement. In the smelting furnaces of the Ural, where the quantity and velocity of the blast are properly regulated, 1.4 of pig iron is obtained by 1 of charcoal fuel, while in other furnaces they obtain but .4 and .6 by the same consumption of fuel.

The velocity of the blast being increased, the heat within is increased, without a corresponding consumption of fuel. In an experiment made by order of the government, it was found that one hundred cubic feet of air, under a pressure of two inches of mercury, produced the same effect as two hundred cubic feet, under a pressure of one inch, with this difference, that in the latter case, twice the fuel was consumed which was required in the former case.

In one furnace which is mentioned, 22,000 lbs. of iron were obtained in twenty-four hours, by 16,000 lbs. of charcoal. Previous to the due regulation of the draught, they consumed twice this amount of fuel for the same yield of iron.

This economy is obtained by duly proportioning to each other the size of the blast-pipe, and the pressure of the draught. The relation of these to each other varies with the furnace.

M. Teploff asserts that the results thus obtained exceed those with the hot-air blast; but it does not appear that any comparisons have been made under his examination, and with the charcoal fuel.

To regulate the draught, it is recommended to place two mercury or water-gauges, one near the blast pipe, the other near the governor of the blowing-machine. By varying the pressure, and the diameter of the nozzle of the blast-pipe, making the latter smaller as the former is increased, and *vice versa*, the best proportion is to be ascertained.—*Annales des Mines*, vol. vii. G.

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*Receipt for fastening Leather upon Metal.*

A. M. Fuchs, of Bairère, says that in order to make leather adhere closely to metal, he uses the following method:—The leather is steeped in an infusion of gall nuts; a layer of hot glue is spread upon the metal, and the leather forcibly applied to it on the fleshy side. It must be suffered to dry under the same pressure. By these means the adhesion of the leather will resist moisture, and may be torn sooner than be separated from the metal.

Athenæum.

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*Novel Experiments on Railways.*

Since the opening of the Durham and Sunderland Railway, a novel experiment has been tried upon the line, which proves the practicability of railroad vehicles being propelled by wind. A temporary mast and sail we e

erected on a vehicle, which was set going at an easy rate. On the sail being trimmed to the wind, the speed increased to the rate of ten miles an hour. A train of five coal wagons was afterwards attached, but no additional sail hoisted. The train was set going as easy as possible to give it motion, when the speed increased to the rate above mentioned. The experiment was repeated for several days between Sunderland and Hendon, each way, with the same success, and was witnessed by numbers of spectators, who were much delighted with the novelty of the scene. Mining Jour.

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There are no Occulations of the Planets and fixed Stars of the 6th magnitude or above, visible at Philadelphia in the month of March.

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## *Meteorological Observations for November*, 1836.

| Moon. | Days. | Therm. Sun rise. | Therm. 2 P.M. | Barometer. Sun rise. | Barometer. 2 P.M. | Wind. Direction. | Wind. Force. | Water fallen in rain. | State of the weather, and Remarks. |
|---|---|---|---|---|---|---|---|---|---|
| | | | | Inches | Inches | | | Inches. | |
| ☽ | 1 | 26° | 47° | 30.2 | 30.06 | NE. | | | Clear—clear. |
| | 2 | 36 | 41 | 29.60 | 29.63 | NE. | | .70 | Cloudy—rain. |
| | 3 | 40 | 46 | 29.65 | 29.65 | W. | | | Cloudy—clear. |
| | 4 | 34 | 42 | 29.80 | 29.80 | W. | | | Cloudy—clear. |
| | 5 | 29 | 46 | 29.86 | 29.86 | W. | | | Cloudy do. |
| | 6 | 32 | 49 | 29.90 | 29.90 | W. | | | Clear—partially cloudy. |
| | 7 | 33 | 50 | 29.94 | 29.91 | W. | | | Clear day. |
| | 8 | 40 | 54 | 29.95 | 29.88 | W. | | | Clear day. |
| | 9 | 32 | 53 | 30.15 | 30.25 | E. | | | Cloudy—hazy. |
| | 10 | 38 | 52 | 30.30 | 30.20 | E. | | | Clear—cloudy. |
| | 11 | 32 | 54 | 30.00 | 29.99 | SE. | | .12 | Clear—cloudy—rain in night. |
| | 12 | 37 | 64 | 29.93 | 29.94 | SW. | | .59 | Cloudy—rain. |
| | 13 | 39 | 49 | 29.90 | 29.94 | W. | | | Clear day. |
| | 14 | 41 | 42 | 29.95 | 29.86 | E. | | | Clear day. |
| | 15 | 38 | 45 | 29.77 | 29.70 | W. | | .85 | Rainy day. |
| | 16 | 36 | 44 | 29.72 | 29.71 | W. | | | Cloudy—clear. |
| | 17 | 33 | 42 | 29.95 | 30.05 | W. | | .08 | Cloudy—clear—rain. |
| | 18 | 43 | 43 | 30.10 | 30.25 | W. | | | Clear—flying clouds. |
| | 19 | 32 | 41 | 30.31 | 30.34 | NE. | | | Clear day. |
| | 20 | 32 | 49 | 30.25 | 30.14 | ESE. | | | Clear day. |
| | 21 | 55 | 56 | 29.65 | 29.65 | SW. | | .61 | Partially cloudy. |
| | 22 | 40 | 46 | 29.80 | 29.80 | W. | | | Rain—flying clouds. |
| | 23 | 30 | 36 | 29.70 | 29.60 | W. | | | Clear—flying clouds. |
| | 24 | 30 | 40 | 29.50 | 29.50 | W. | | | Clear—cloudy. |
| | 25 | 24 | 39 | 29.60 | 29.60 | W. | | | Clear—snow squalls. |
| | 26 | 26 | 32 | 29.70 | 29.70 | W. | | | Clear—squally. |
| | 27 | 26 | 34 | 29.94 | 29.94 | W. | | | Cloudy day. |
| | 28 | 34 | 34 | 30.00 | 30.00 | W. | | | Clear day. |
| | 29 | 30 | 39 | 29.80 | 29.62 | W. | | | Lightly cloudy—cloudy. |
| | 30 | 35 | 42 | 29.62 | 29.52 | W.SW. | | | Lightly cloudy—cloudy. |
| | Mean | 11 10 | 14.37 | 29.89 | 29.87 | | | 2.96 | Partially cloudy—clear. |

| Thermometer. | | | Barometer. | |
|---|---|---|---|---|
| Maximum height during the month | | 64. on 11th & 12th | 30.34 on | 19th |
| Minimum | do. | 34. on 25th. | 29.50 on | 24th. |
| Mean | do. | 29.38. | 29.88. | |